electrical systems

Reference Book

STST

Service Technician Specialty Training

Ford Parts and Service Division
Technical Training

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advise or cautions as to each. Accordingly, anyone who departs from the instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, AND WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general warnings that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine on) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind the head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents if available may be used. The right is reserved to make changes at any time without notice.

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INTRODUCTION

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PURPOSE OF THIS COURSE

This course is designed to technically qualify participants to service the electrical systems used by Ford Motor Company. The course covers basic electrical concepts as well as the construction of electrical circuits and components. Diagnosis, the use of wiring diagrams and measuring devices, and electrical system repairs are also covered.

TECHNICAL TRAINING CURRICULUM

This course is a part of the Ford Service Technician Specialty Training (STST) curriculum. All STST curriculum courses are designed for specific technician specialty areas. The courses are designed for technicians with basic understandings of their expressed specialties. A technician may be required to attend one or more STST courses, depending upon his or her specialty.

A technician must complete all mandatory pre-requisite courses and pass a qualifying pretest to be eligible to attend any STST course.

Each technician must complete a posttest which includes some hands-on evaluation to be considered a trained specialist.

HOW TO USE THIS REFERENCE BOOK

This book contains all of the information that is presented in the course. It also includes worksheets and exercises that will help you learn this material. Your instructor will assign portions of this book as homework during the course. Be sure to complete all assignments given to you. After you have completed the course, keep this book for future reference.

Read 1, 2, 3, 4

AXOD 1989 H manual

Test 44[illegible]9 17-351
[illegible]T90 17-36[illegible]5
T366
T92 if code 68 is present change processor

LESSON AGENDA

LESSON 1: INTRODUCTION TO ELECTRICITY

CONTENT

- Current, Voltage, Resistance
- Conductors, Insulators
- Vehicle Electrical Sources

INSTRUCTOR OBJECTIVES

The instructor will:

- Identify current, voltage and resistance
- Define units of measurement and the different symbols
- Introduce and discuss sources of electricity on vehicles
- Provide technician with actual experience in a real life situation

TECHNICIAN OBJECTIVES

The technician will:

- Identify the sources of electricity
- Name the units of measure used in electricity
- Relate basic electrical principles to automotive applications

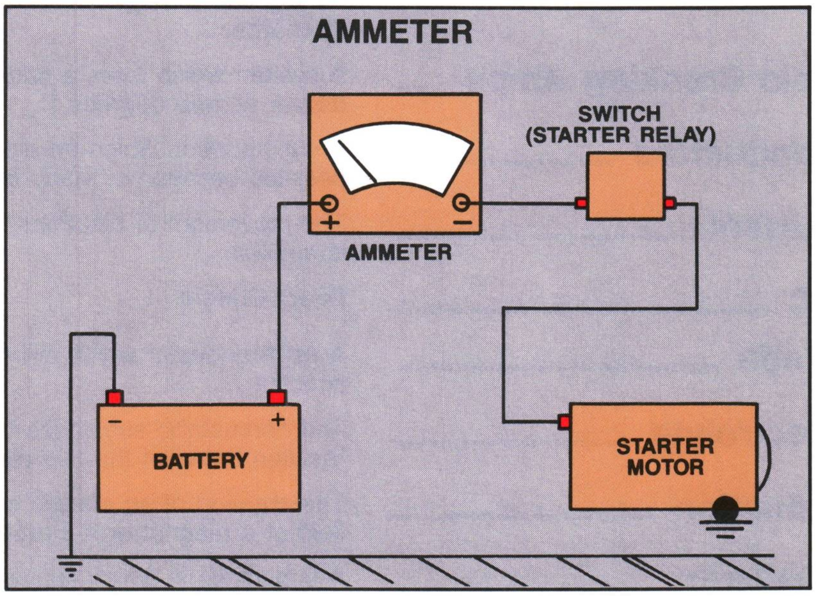
LESSON 1 GLOSSARY

AC	Alternating Current - An electric current which reverses direction in the conductor. The flow in the conductor is created by repeatedly changing the polarity of the source field.
Ammeter	A device used to measure current flow or amps.
Amperes	The unit of measure for electric current.
Amp Hours	A system which rates battery capacity to perform work by placing the battery under a specified load and measuring the time required to discharge.
Cold Cranking Amps	A system which rates a battery by the amount of current it can deliver at zero degrees F.
Conductors	A substance in which an electric current will flow. Current flow is possible because of many free electrons in the substance.
Current	The movement of electrons in a conductor when electromotive force is applied.
DC	Direct Current.
Diode	A semiconductor which will only permit current to flow in one direction.
Electrolyte	The nonmetallic substance in a battery which promotes a chemical reaction between the two electrodes.
Induction	The creation of an electric current in a conductor by placing it in the field of a magnet or a current carrying conductor.
Insulator	A substance in which current will not flow because of a lack of free electrons.
Load	A device in an electrical circuit that converts current flow to heat, light or motion.
Magnetic Field	The field surrounding a magnet or current carrying conductor.
Ohmmeter	Device used to measure resistance.
Ohms	The unit of measure for resistance to current flow.
Resistance	A substance in which current flows at a limited rate. Resistors have fewer free electrons than conductors.
Semiconductor	A material that can be made to conduct or not to conduct electricity
Sulphated	A condition which will no longer allow a lead/acid battery to hold a charge.
Thermocouple	A device which generates electricity when it is heated.
Voltage	The electrical pressure in a circuit.
Voltage Drop	The change in electrical pressure between any two points in a circuit.
Voltmeter	A device used to measure voltage.
Volts	The unit of measure for electrical pressure or electromotive/force.

CURRENT

Current is the flow of electricity through the circuit. It is measured in **amperes** or amps. The letter A is the symbol for amps. A device called an **ammeter** is used to measure current flow in a circuit. The ammeter is placed in SERIES with the device to be measured. Power to the circuit must be ON to make a current measurement since the ammeter measures the amount of current that flows through the meter.

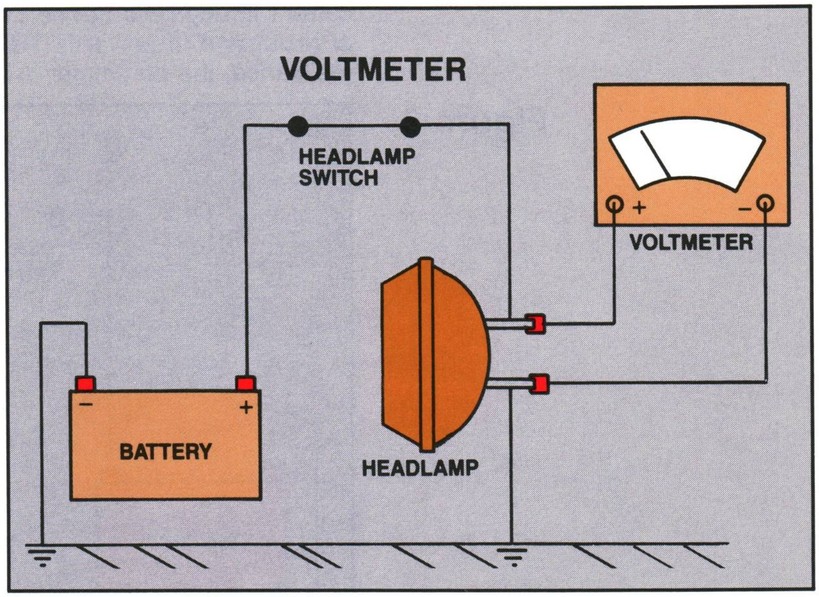
Figure 1



VOLTAGE

Voltage is the electrical force or pressure that causes current to flow through an electrical circuit. Voltage is measured in **volts**. The letter V is the symbol for volts. A device called a **voltmeter** is used to measure voltage in a circuit. The meter is placed ACROSS the device to be measured. Power to the circuit must be ON to make a voltage measurement.

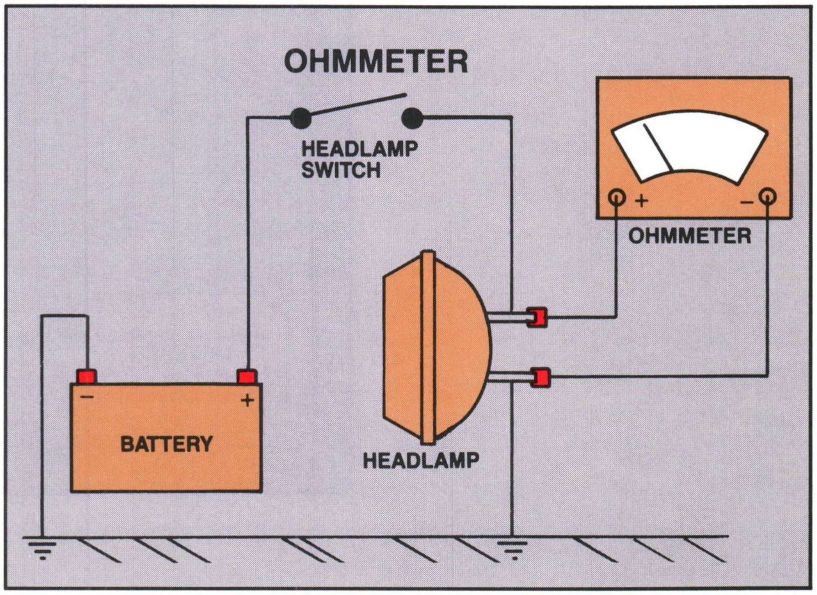
Figure 2



RESISTANCE

Resistance is the opposition to the flow of electrical current through an electrical circuit. It resists the flow. Resistance is measured in **ohms**. The greek letter Ω is the symbol for ohms. A device called an **ohmmeter** is used to measure resistance in a circuit. The ohmmeter is placed ACROSS the device to be measured and the power to the circuit must be OFF when the resistance measurement is made. The ohmmeter sends a small amount of current through the device being measured to determine the amount of resistance. If power is TURNED ON when you measure resistance, the ohmmeter WILL be damaged.

Figure 3



As electricity flows through a resistance, the resistance will heat up. This is what happens in a light bulb. As the electricity flows through the bulb, the filament of the bulb resists the flow of electricity and heats up to the point that it glows. A typical vehicle application using resistance heating would be in the rear window defogger. As electricity flows through the grid in the rear window, its high resistance to current flow causes the wires in the grid to get hot and warm the glass.

Another characteristic of a resistance in a circuit is that it lowers the voltage. You can think of this as some of the voltage being used up as the electricity flows through the resistance. This lowering of voltage is called **voltage drop**. A typical vehicle application of voltage drop is to control the speed of a blower motor. As the blower motor control is switched from low to high, the resistance in the circuit is reduced and more voltage flows to the blower motor and the motor runs faster.

Voltage drop will occur when electricity is used by a component on the vehicle to do some work such as turning on lights, running the starter motor, playing the radio, operating the rear window defogger, etc. Vehicle components that do work are called **loads**. Thus loads in the circuit will cause a voltage flowing through the circuit just as resistances do.

CONDUCTORS

INSULATORS

The wires in the vehicle electrical system are covered with a material that will not conduct electricity (it has a very high resistance). The material is called an **insulator**. It keeps the electricity in the wire and away from the other parts of the vehicle just as the hose keeps the water from leaking out before it gets to the garden.

In the vehicle electrical system the current is carried by wires just as the hose carries the water from the house to the garden. The wires are called **conductors** since they conduct the electricity through the circuit.

SEMICONDUCTORS

In some water systems there are one way valves or check valves that allow the water to flow only in one direction. Electrical systems also have one way valves that allow electricity to flow only in one direction through the wire, these are called **diodes**. Diodes are used in the alternator to convert the alternating current (**AC**) generated by the alternator to the direct current (**DC**) which is used by the vehicle. Diodes are made out of material that conducts electricity only in one direction. The material is called a **semiconductor**.

VEHICLE ELECTRICAL SOURCES

The two major sources of electricity on a vehicle are the battery and the alternator.

BATTERY

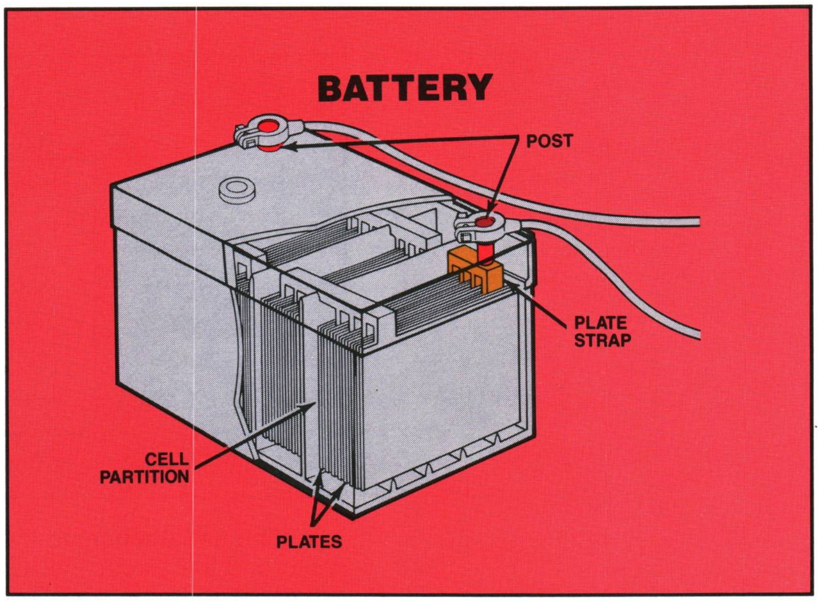
The battery supplies electricity to the vehicle electrical system when the engine is not running and the alternator supplies electricity to the vehicle electrical system and to the battery when the engine is running.

The battery used in a vehicle is called a storage battery. It has the ability to be store electricity and be recharged after the stored electricity is used up. The electricity in the battery is generated by chemical action.

The three key parts of a storage battery are the:

- POSITIVE PLATE - Lead Peroxide (PbO_2)
- NEGATIVE PLATE - Sponge Lead (Pb)
- ELECTROLYTE - Sulfuric acid (H_2SO_4) and Water (H_2O)

Figure 4

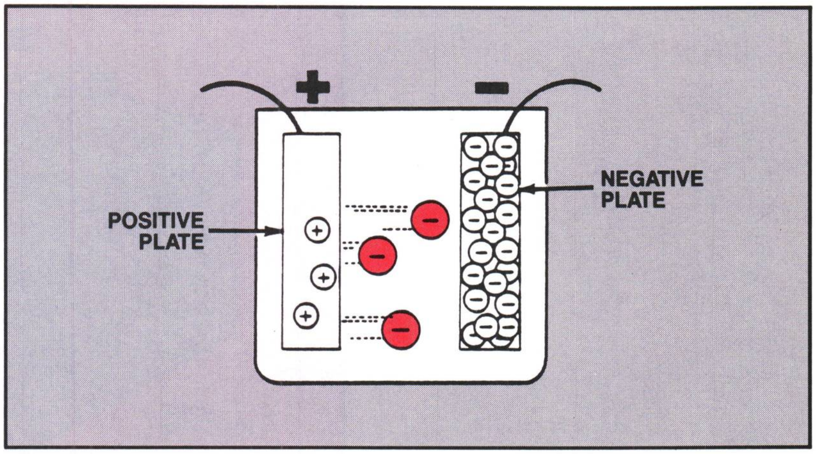


In a lead acid battery, each cell is made up of positive and negative plates. A plate strap connects all of the positive plates and a second plate strap connects all of the negative plates. A porous insulating material is placed between the plates to prevent them from touching and shorting the battery. This arrangement greatly increases the capacity or power of each cell by increasing the surface area where the chemical action can take place. Each cell is connected to the next in series (positive to negative) to produce the higher voltage required to power the vehicle. Each cell produces 2.3 volts and by connecting six cells in series, a 12 volt automotive battery actually produces 13.2 volts when fully charged. Nominal loses at the input connections will usually reduce the output voltage to about 12.6 volts.

Automotive batteries are manufactured in various sizes to meet the needs of many different applications. The capacity of the battery is given in either **Amp Hours** (AH) or **Cold Cranking Amps** (CCA). Amp hours is determined by placing a specific load on the battery and measuring the time required for it to discharge. Cold Cranking Amps is the amount of current the battery is capable of delivering at 0 degrees F. Both are accurate indicators, but CCA is more commonly used today.

When the battery plates are submerged in the **electrolyte** (36% acid and 64% water), the cell develops a voltage due to the chemical action on the lead plates.

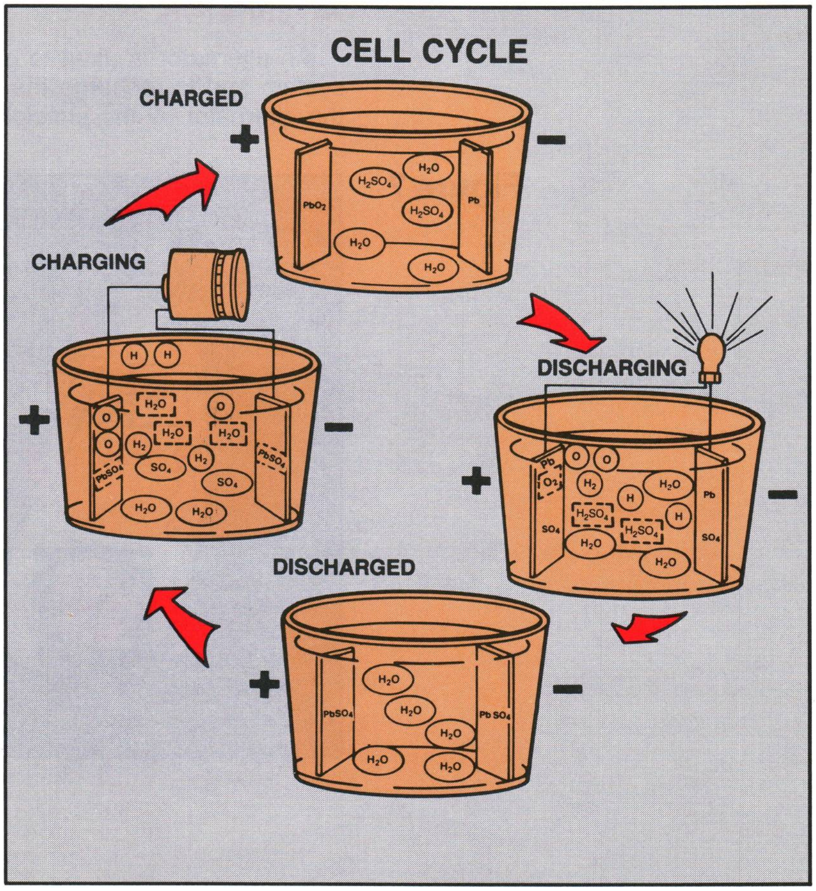
Figure 5



As the cell discharges the plates become more and more the same and the electrolyte becomes more and more water. Electrons are supplied to the negative plate to replace those being drawn off into the circuit as long as the plates are dissimilar and the electrolyte does not revert to water.

During the charge phase the action is reversed. Electricity is moved into the battery by the alternator during the charging cycle. The lead sulfate of both plates reverts to its original state of pure lead and lead sulfate and the electrolyte changes back to a more acid mix.

Figure 6

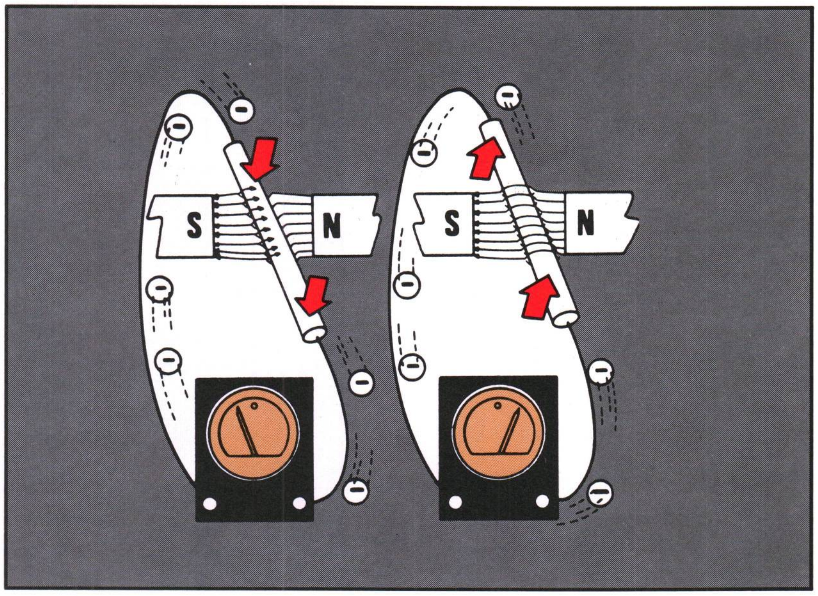


Discharging and charging the battery over and over will eventually wear out the components, since the chemicals reversals are never 100% effective. Finally the battery will reach a state where the plates cannot be made dissimilar through the application of electric current. At this point the battery is said to be **sulfated** and a replacement is required.

ALTERNATOR

An alternator is used to generate electricity for the electrical system and to recharge the vehicle battery. Electricity is generated in the alternator by the principle called **induction**.

Figure 7



Induction takes place when a conductor is passed through a **magnetic field**. As the conductor is passed through the magnetic field an electric current is generated. In order to create electricity the magnetic field or the conductor must be moving. This can be accomplished by:

- Moving the conductor through a stationary magnetic field.
- Moving the magnetic field past a stationary conductor.
- A magnetic field building and collapsing through a conductor.

The voltage generated is determined by the strength of the magnetic field and the speed with which the magnetic field is cut. This is why the lights of the vehicle get brighter when you race the engine. The increase in engine speed causes the alternator to turn faster and more electricity is generated. The voltage to the lights increases and they get brighter.

OTHER SOURCES OF ELECTRICITY ON VEHICLES

There are other sources of electricity on a vehicle. These sources are rather small and are used to send signals to other items in the electrical system. A typical source is the anti-lock wheel speed sensor.

The anti-lock wheel speed sensor uses the principle of induction to send wheel speed information to the anti-lock controller.

LESSON 2: BASIC CIRCUIT CONSTRUCTION

CONTENT

- Elements of Basic Circuit
- Circuit Control and Protection
- Circuit Arrangements

INSTRUCTOR OBJECTIVES

The instructor will:

- Introduce basic circuit elements
- Discuss relationship between current flow and resistance of load
- Describe how current will flow through series circuit, parallel circuits and series-parallel circuits
- Provide technician with actual experience in a real life situation

TECHNICIAN OBJECTIVES

The technician will:

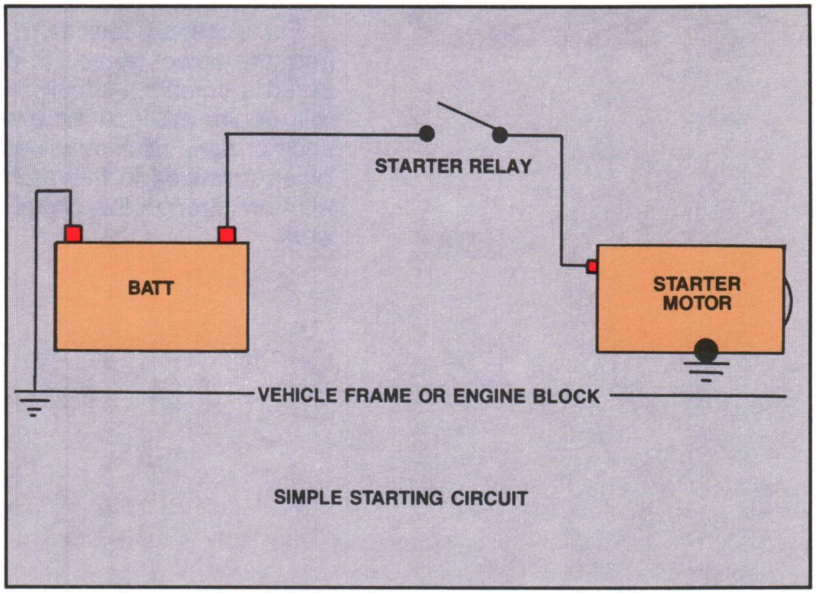
- Identify the basic elements of a circuit
- Demonstrate the ability to distinguish between series circuits, parallel circuits and series-parallel circuits
- Apply relationship between current and load (resistance) in basic circuits
- Construct all three basic circuits on the bench

BASIC CIRCUIT CONSTRUCTION

Basic Circuit

For electrical devices to operate, there must be a complete path from the power source to the device and back. This circular path is called a complete circuit or **closed circuit**. In most basic circuits, this will require a conductor from the source of power to the **load** and another conductor returning to the source of power as a **ground**. When arranged in this manner, the circuit will be closed and current will flow through the circuit and loads in the circuit will produce useful work.

Figure 8



SIMPLE STARTING CIRCUIT

In a vehicle it is not practical to have a separate ground wire returning to the battery for each system since it could double the amount of wires in the vehicle. Therefore, most circuits are completed with a ground circuit that uses the vehicle body, engine or frame as the return path to the power source. The steel of the body, engine and chassis structure provides an excellent path for electric current.

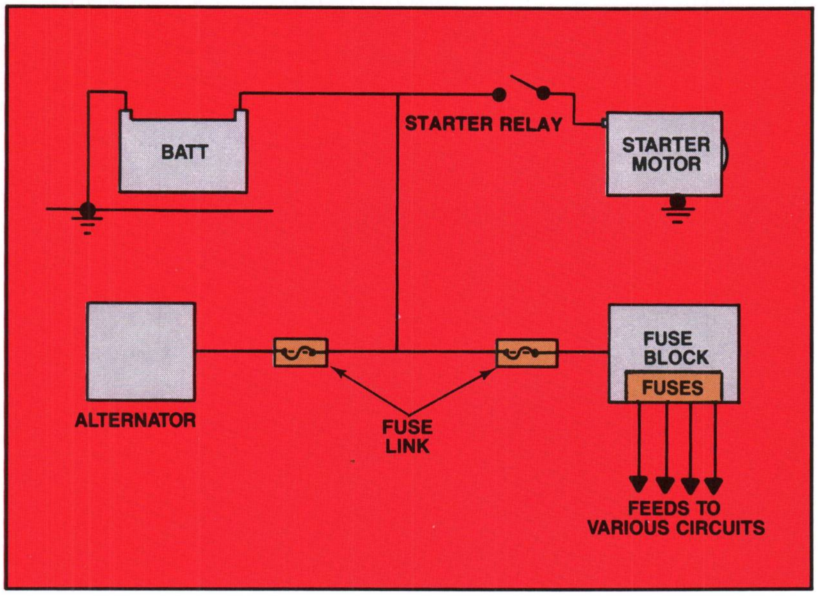
If either of the conductors is removed from the load or the power source, the circuit is broken. Because there is no longer a complete path, current will not flow. This is referred to as an **open circuit**. In this situation, voltage will be available in the circuit only to the point of the break.

If an unwanted path is created between the positive side of the circuit and the ground side, so that the current flows around the load, a **short circuit** is said to exist. Since the load limits the amount of current flowing in a circuit, a short will cause a very large current flow. It is important to remember that an electric current will always flow through the path offering the least resistance.

CIRCUIT CONTROL AND PROTECTION

To make a basic circuit more usable, a control device must be added. A **switch** in a circuit will complete the path and allow current to flow when it is closed. When the switch is opened, the path is broken and current will not flow. The location of the switch in a circuit makes no difference, if the path is broken current cannot flow.

Figure 9



In the basic circuit, when an alternate path was provided around the load, a short circuit was said to exist. Without some means of protecting the circuit, a short circuit would allow an unlimited amount of current to flow, and the wiring would overheat and burn. To prevent this condition, a circuit must contain a **fuse**. A fuse is nothing more than a section of conductive material that is smaller in size than the circuit conductors. If a short circuit occurs, the fuse material will overheat due to the excessive current flow and melt. This will open the circuit path and prevent any damage to the components. Fuses are one type of circuit protector. They are rated in amperes. In a circuit protected with a ten amp fuse, if the current exceeds ten amps the fuse will open thus protecting the circuit. **Fuse links** are another type of circuit protector, but they are not as easily replaced as fuses.

CIRCUIT ARRANGEMENTS

Circuits can be arranged in three ways:

- Series,
- Parallel, or
- Series/Parallel

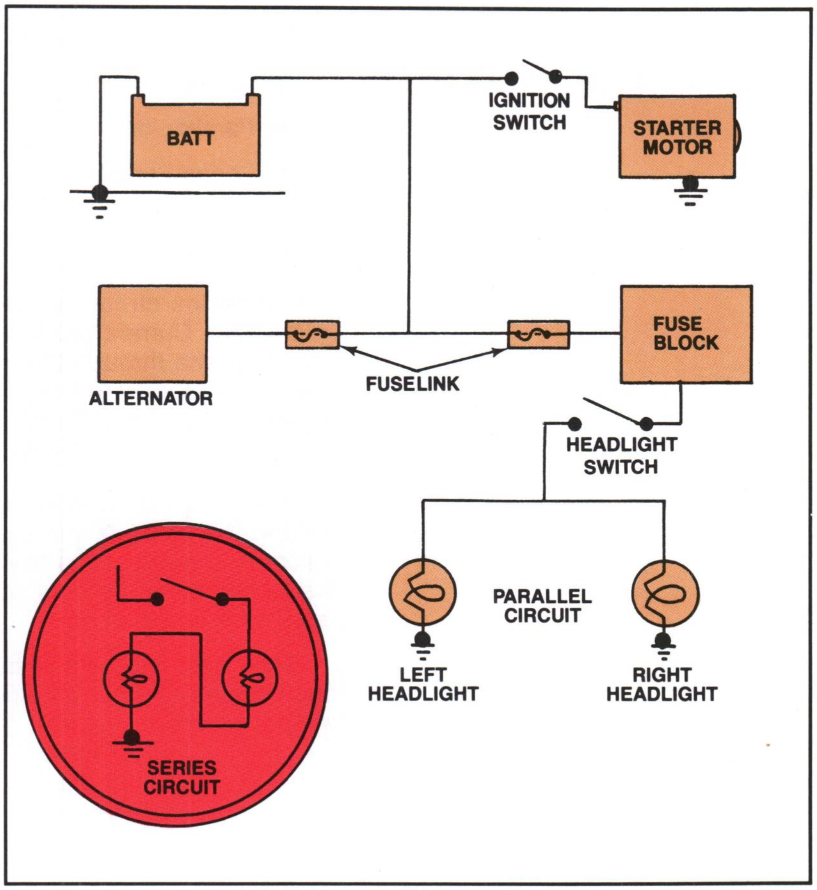
SERIES CIRCUITS

In a **series circuit**, all of the loads are arranged one after another in a series. Current passes through each load and returns to the power source through the ground circuit. Since each load has some resistance to current flow, the more loads you connect in series, the higher the total circuit resistance, and the lower the voltage becomes as the result of the voltage drop across each load.

The voltage in a series circuit can be increased or decreased by varying the resistance in the circuit. This principle is used in automotive applications to control loads. The brightness of the instrument panel lights is controlled by increasing or decreasing resistance in the circuit.

Since only one path of current flow exists in a series circuit, if an open occurs, the current flow will cease and the loads in the circuit will not function.

Figure 10



PARALLEL CIRCUITS

In a **parallel circuit**, the loads are arranged with individual paths for current flow. Current divides into two branches at the splice, and each branch has its load and a separate ground. If either load is disconnected, the other will continue to operate because of its separate path to ground.

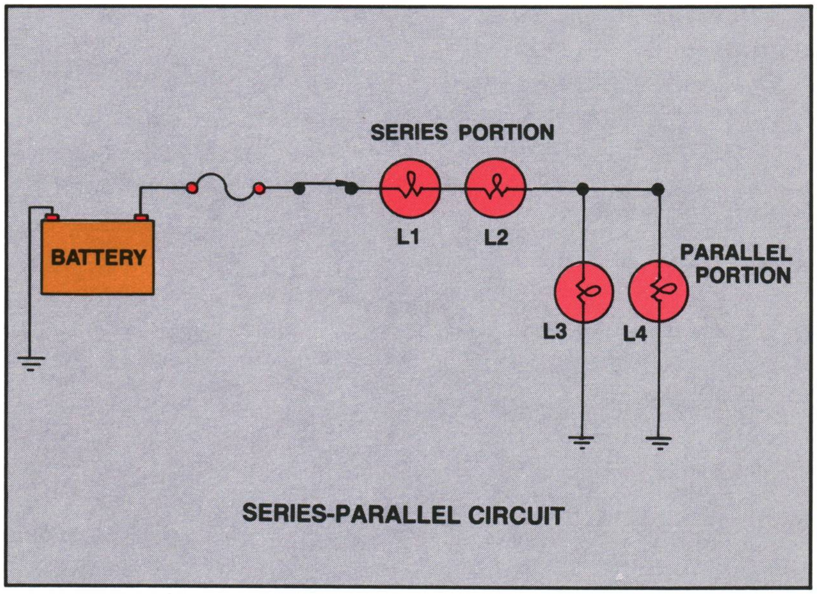
When loads are placed in parallel, total resistance in the circuit is less than the resistance of either load. This is because the current has more than one path to ground. Because of this, current flow in a parallel circuit will increase as you add more loads. Just the opposite of a series circuit.

SERIES-PARALLEL CIRCUITS

A **series-parallel circuit** is a combination of a series circuit and a Parallel circuit. Like a series circuit, the branch with loads connected in series will have a resistance equal to the total of the loads added together. The branch with loads in parallel will have a total resistance less than the resistance of either load. Current flow will be different in each branch of the circuit even if all of the loads have the same resistance.

Figure 11

SHOP SESSION



SERIES-PARALLEL CIRCUIT

LESSON 3: ELECTRICAL MEASURING DEVICES

CONTENT

- Electrical measuring devices
- Use measurement devices to make measurements in series and parallel circuits
- OHMs Law and how it relates to the measurements made

INSTRUCTOR OBJECTIVES

The instructor will:

- Introduce the technician to types of meters available and what each measures
- Discuss the value of accurate electrical measurements in diagnostics
- Provide hands-on experience in taking electrical measurements of voltage, amperage and resistance
- Discuss OHMs Law and relate it to the measurements taken

TECHNICIAN OBJECTIVES

The technician will:

- Identify the types of electrical measurement devices and what each measures
- Explain the importance of accurate electrical measurement
- Demonstrate the ability to use various electrical measuring devices interpret the readings
- Demonstrate OHMs Law in measuring voltage, resistance and current

LESSON 3 GLOSSARY

Ammeter	A test instrument which measures current flow in a circuit.
Analog Meter	An electrical test meter which uses a spring-loaded needle and a magnetic field to indicate a circuit value on the meter scale.
Continuity Tester	A device used to test electrical circuits for a complete circuit path. A light bulb and dry cell battery are contained in the probe handle. The bulb will light when the two ends of the tester are connected to a complete, unpowered circuit.
Digital Meter	An electrical test meter which displays the measured value in numeric form.
DVOM	Digital volt/ohm meter.
Inductive Ammeter	An ammeter which utilizes the principle of magnetic induction to measure current flow in an electrical circuit. This type of meter is typically used for measuring large currents such as starting and charging systems.
Internal Shunt Ammeter	An ammeter which is connected in series with the circuit to be tested. These meters are used typically in circuit tests where current flow is less than 10 amps.
Jumper Wire	A length of wire with probes or clips at each end used to bypass a portion of a circuit.
Ohmmeter	An electrical test instrument used to measure the resistance in an electrical circuit.
Ohm's Law	A series of formulas which are used to determine the values in an electrical circuit. Any two of the values can be multiplied or divided to determine the third unknown value.
Self Powered Test Light	A device used to check for continuity in a circuit. It has an internal battery which supplies current to the circuit being tested. The test light will come on if continuity exists. It is sometimes called a continuity tester.
Voltage Drop	The change in electrical pressure between any two points in an electrical circuit. The amount of voltage drop between two points in a circuit will be determined by the resistance of the circuit loads and the number of loads in a circuit.
Voltmeter	An electrical test meter which measures electrical pressure (EMF).
12 Volt Test Light	A device used to check for voltage in a circuit. A 12 volt bulb is located in the probe handle, and will light when one end of the device is grounded and the other is connected to a power source.

Accurate measurement and analysis of an electrical circuit is limited by the accuracy of the measuring instrument being used. The ability of a technician to read the instrument correctly and to interpret the reading will require that you know how to:

1. CALIBRATE the test instrument.
2. CONNECT the instrument properly.
3. SELECT the proper measuring range.

MEASUREMENTS

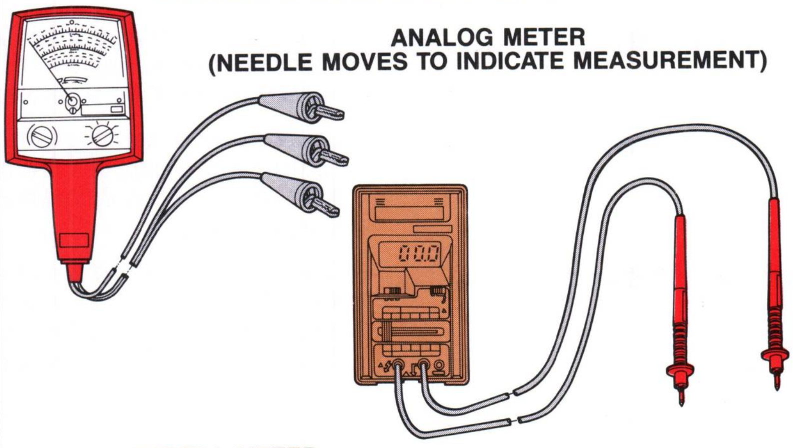
Items that are measured with test equipment include:

- Voltage
- Resistance
- Amperage
- Continuity (if circuit is open or closed)

TYPES OF TEST INSTRUMENTS

Figure 12

ANALOG/DIGITAL METERS


ANALOG METER
(NEEDLE MOVES TO INDICATE MEASUREMENT)
DIGITAL METER
(NUMBERS INDICATE MEASUREMENT)

Meters are available that measure volts, ohms, and amps. Most meters in use today are capable of measuring all three values and are called **multimeter**.

Two types of meters available for making electrical measurements are analog and digital meters.

ANALOG METERS

Analog meters have a spring loaded needle that moves along a scale in relation to the value being measured. The value of the measurement is actually a comparison of the circuit or components and a known value built into the meter, which you read directly from the scale. Judgment on the part of the user is required to determine the value displayed on the meter, since the scale may be used for more than one range.

Examples of Analog Meters include:

- VOLTMETER - used to measure electrical pressure.
- OHMMETER - used to measure resistance.
- AMMETER - used to measure current.
- MULTIMETER (volt/ohm/amps) - used to measure volts, ohms and amps.

DIGITAL METERS

Digital Meters display the value of the measurement in digits on the face of the meter. They are electronic, very sensitive and can be used to measure standard circuits as well as electronic circuits which have relatively low operating current. They are the most accurate of all instruments, because less judgment is required by the user to interpret the reading. Many feature automatic range adjustment, automatic polarity adjustment, and accuracy to several decimal points. Like the analog meter, digital meters compare the value being measured to a known value.

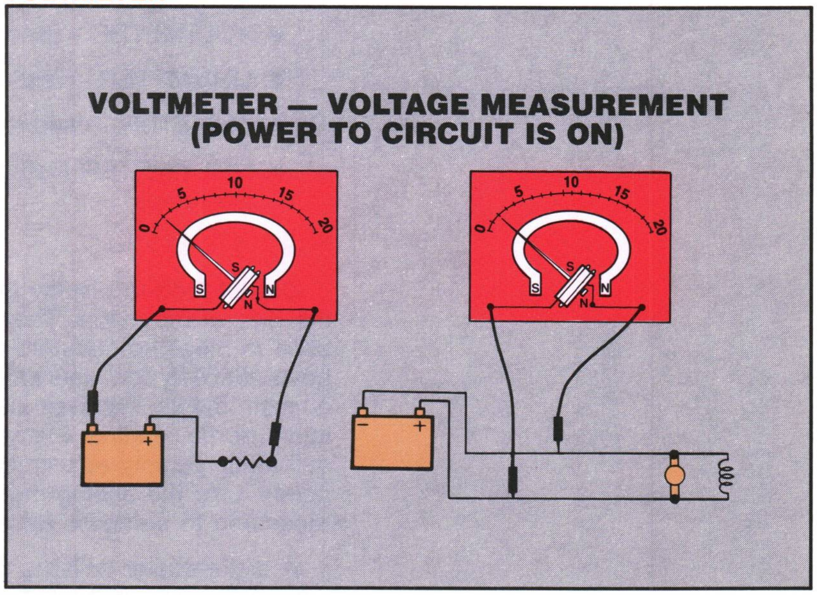
A digital meter called a **DVOM** (digital volt/ohmmeter) is used to measure volts, amps, and ohms. This type of meter is often referred to as a **multimeter**.

CAUTION: Electronic circuits and electronic components can be seriously damaged if they are tested with test equipment that delivers or draws excessive current. Equipment designed for use with electronic circuits should always be used. All measurements of electronic circuits must be made with DIGITAL METERS unless the testing procedure states otherwise.

HOW TO USE THE TEST EQUIPMENT

Figure 13

VOLTMETER

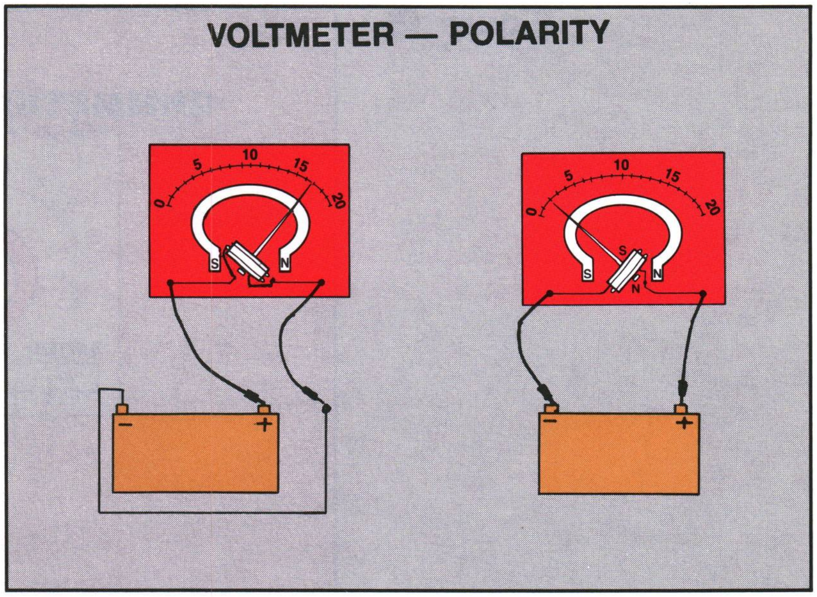

VOLTMETER — VOLTAGE MEASUREMENT (POWER TO CIRCUIT IS ON)

The **voltmeter** is the most widely used of all electrical test instruments. In addition to reading available voltage in a circuit, the voltmeter can be used to detect **voltage drop** between any two points in a circuit. When a voltmeter is connected in parallel with a circuit that has a difference in voltage (pressure), current will flow through the meter. The current passing through the meter is then compared to a known value and the result is displayed on the scale.

In most good quality meters, the known value is supplied by an internal circuit powered by a dry cell battery. If the internal battery is weak, inaccurate readings will result. Therefore, a periodic check of the internal battery should be made to ensure accurate results. Most digital meters have an indicator on the display to warn you of a low battery condition.

In some analog meters, a permanent magnet is used to provide the comparison. These meters can be very accurate and are identified by the lack of an OFF position on the range switch. The volt position acts as the OFF position.

Figure 14



To make a voltage measurement, power to the circuit must be ON and the meter leads are connected across the component to be measured.

Voltmeters are polarity sensitive, that is, they will show positive or negative voltage. In digital meters a plus (+) or minus (-) will proceed the reading. In analog meters you may have to reverse the leads to get a reading.

Voltmeters also have a number of scales that can be selected to change the RANGE of the meter. The number of scales varies from one meter to the next. The scale selected should be the one that will give the most accurate reading.

Typical analog scales are:

- 2 volts
- 20 volts
- 200 volts

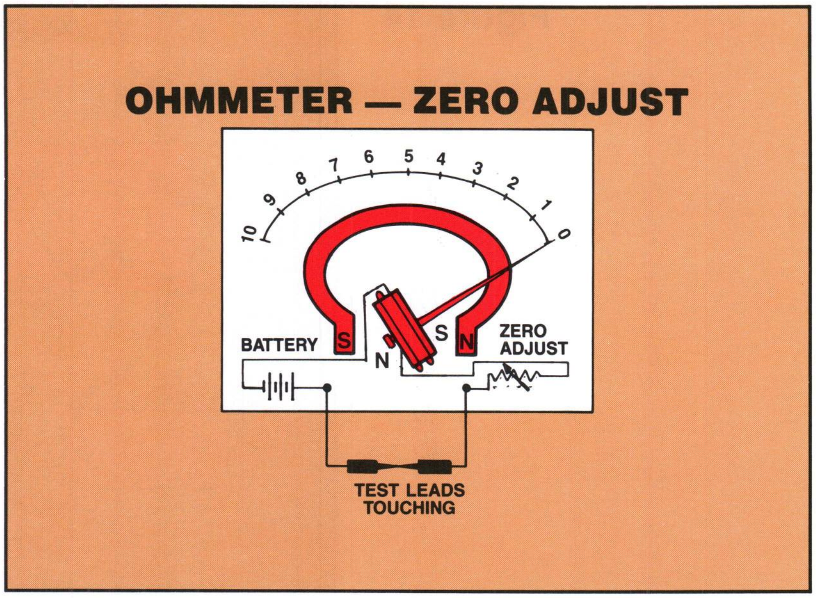
Typical digital scales are:

- 200 mV
- 2000 mV
- 20 volts
- 200 volts
- 1000 volts DC
- 750 volts AC

OHMMETER

The **Ohmmeter** is a physical representation of Ohm's Law: know two of the values and you can find the third one. By applying a known voltage to a circuit and comparing the current flow to a value built into the meter, the resistance of the circuit is determined.

Figure 15

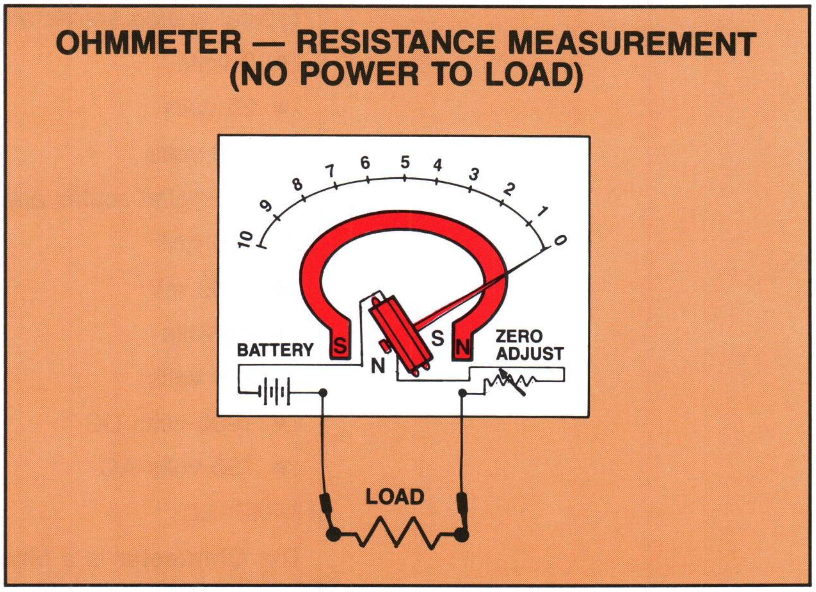


Before using the ohmmeter, the meter must be "zeroed" - calibrated to read zero ohms. This is done to insure an accurate reading. The meter calibration must be checked each time you change scales, or inaccurate readings could result.

For analog meters, touch the leads together. The meter needle will swing across to the right side of the dial. To accurately zero the needle, turn the knob labeled "zero set" until the needle aligns with the zero point on the scale.

For digital meters, touch the two leads together. If the display does not read zero, the internal battery is probably weak, and should be replaced before using the meter.

Figure 16



When the leads are not touching or connected to a circuit, the meter will indicate infinite resistance. On an analog meter, the needle will remain at the far left of the scale. On a digital meter, this will appear as "1" or "+1" at the far left of the display.

The ohmmeter has various scales or sensitivities that can be selected to measure a wide RANGE of resistance values. If you don't know the approximate value of the resistance being measured, its good practice to select a higher scale first and work toward the lower scale.

Typical ranges are:

- 200 OHMS
- 20K OHMS
- 200K OHMS
- 2000K OHMS

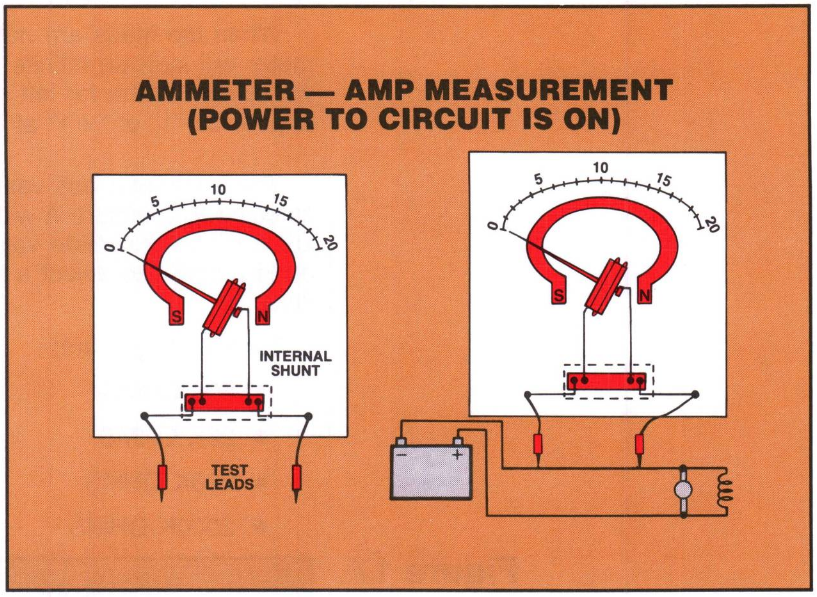
Figure 17

VOLTAGE	**Units**	**Volt**	
	× 1000	**KV**	**Kilovolt**
	× 1,000,000	**MV**	**Megavolt**
	÷ 1,000	**mV**	**Millivolt**
	÷ 1,000,000	**μV**	**Microvolt**
CURRENT	**Units**	**Ampere**	
	× 1000	**KAmp**	**Kiloampere**
	÷ 1000	**mA**	**Milliampere**
	÷ 1,000,000	**μA**	**Microampere**
RESISTANCE	**Units**	**Ω**	**Ohm**
	× 1000	**KΩ**	**Kilohm**
	× 1,000,000	**MΩ**	**Megohm**

To make a measurement, verify there is no power to the component to be measured, and then connect the meter leads across the component. Be sure the component is isolated from other components in the circuit. When the leads are connected across a component to measure the resistance, the meter's internal battery applies a voltage to the component. The resulting current flow through the component is compared to a known value built into the meter. The resistance of the component is then shown on the meter face.

CAUTION: NEVER connect the ohmmeter into a "live" circuit. The current flow through the meter from the circuit voltage can destroy the meter coil instantly. Some meters have internal fuses to protect the meter.

Figure 18



AMMETER

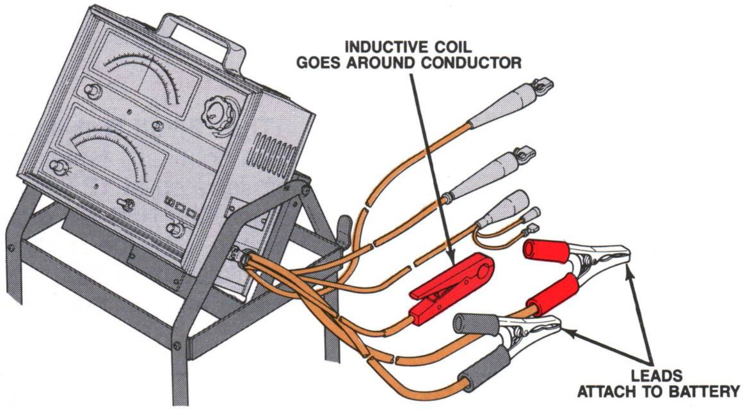
The **ammeter** measures the amount of current flowing in a circuit. There are two basic types of ammeter commonly used for automotive diagnosis. The **internal shunt ammeter** type is used for measuring small amounts of current and is connected in series with the circuit to be tested. Typically, this type of meter will only withstand current of 10 amps or less. Multimeters contain shunt type ammeters. The **inductive ammeter** is used to measure larger current flows such as starting and charging system tests.

The internal shunt ammeter must always be connected in series with the circuit, never across components. If you connect it across a component, you will effectively route the current around the component. When you do this, you risk burning up the meter or the circuit by causing too much current to flow.

When connected into the circuit, current will flow through a fixed resistor in the meter. A second circuit of higher resistance is connected in parallel to the first, and the resulting current flow will cause a reading on the meter. This type of ammeter will provide very accurate readings of small current flows typically found in electronic circuits. The maximum reading on internal shunt ammeters and multimeters is normally 10 amps.

Figure 19

INDUCTIVE TYPE AMMETER
STARTING AND CHARGING TESTER

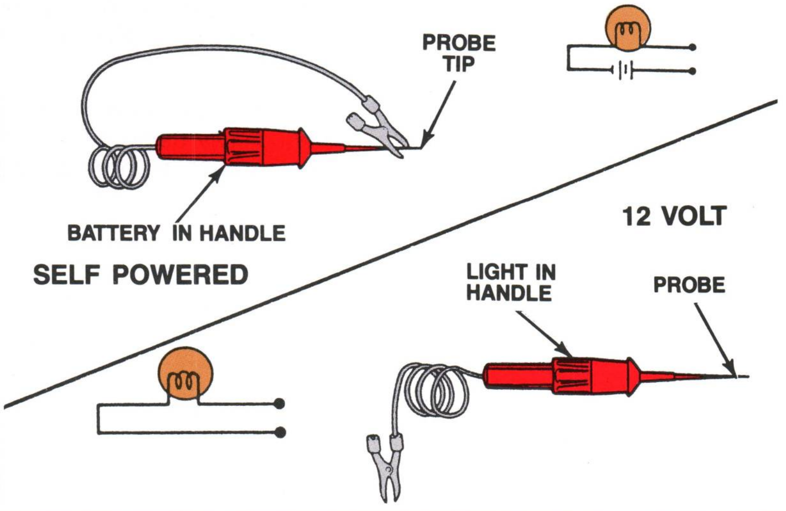


The inductive ammeter uses three connections to read current flow in a circuit. Two heavy cables with spring clamps are attached to the battery posts to supply power to the meter. The third lead has a clamp which contains an iron core that fits around the conductor to be tested. When current flows in the conductor, the magnetic lines of force around the wire induce a current flow in the test lead which flows through the meter and registers on the scale. This type of meter is not recommended for small currents because it was not designed for precise readings below 10 amps.

CONTINUITY TESTER

Figure 20

TEST LIGHTS



A **continuity tester**, or **self powered test light**, will indicate when a circuit has a complete path or continuity. This tool consists of a small dry cell battery and a light bulb housed in a plastic handle, with a pointed probe at one end, and a wire lead with an alligator clip at the other. When connected in series with a circuit, the internal battery will send current through the circuit and the lamp will glow if the circuit has continuity. Continuity testers are a quick check type of tester, and should never be used in place of an Ohmmeter.

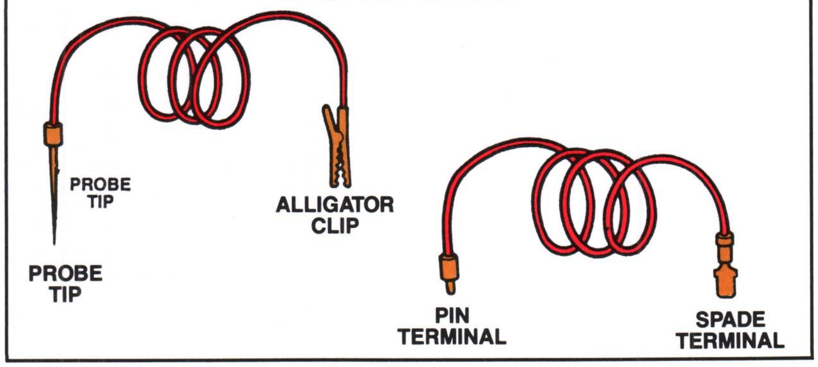
Like an Ohmmeter, a continuity tester should not be connected into a live circuit. Doing so will cause the bulb to burn out.

TEST LIGHT

The **12-volt test light** is used to test for voltage. Most look much like a continuity tester except that there is no internal battery and the bulb is rated at 12 volts. When one end of the light is connected to a ground, the light will glow when a conductor carrying voltage is touched. Like the continuity tester, a test light should never be substituted for a voltmeter, since it will only indicate the presence of voltage and not the amount.

Figure 21

JUMPER WIRES



JUMPER WIRES

Jumper Wires are sometimes used as an aid to diagnosis by providing continuity across components suspected of being OPEN, or supplying battery voltage to the circuit independent of normal switches or wiring. Jumper wires can be equipped with the same type of probes and clips found on continuity testers, and can also be fitted with specialized connectors and terminals for specialized testing.

Continuity of the jumper wires themselves should be checked periodically using an ohmmeter. Any resistance in the connections, could cause an error during diagnosis.

OHM'S LAW CLASS SESSION

Voltage, current and resistance have a specific relationship to the each other. It is important to understand this relationship and be able to apply to electrical circuits since it is the basis for all electrical diagnosis.

George S. Ohm, a scientist of the early 1800's, formulated a law that links the relationship of voltage, current flow and resistance in a basic circuit. He found that "In a circuit, the current is directly proportional to the applied voltage and inversely proportional to resistance in the circuit".

Ohm's Law can be expressed as an equation that shows the relationship between voltage (E), current flow (I), and resistance (R):

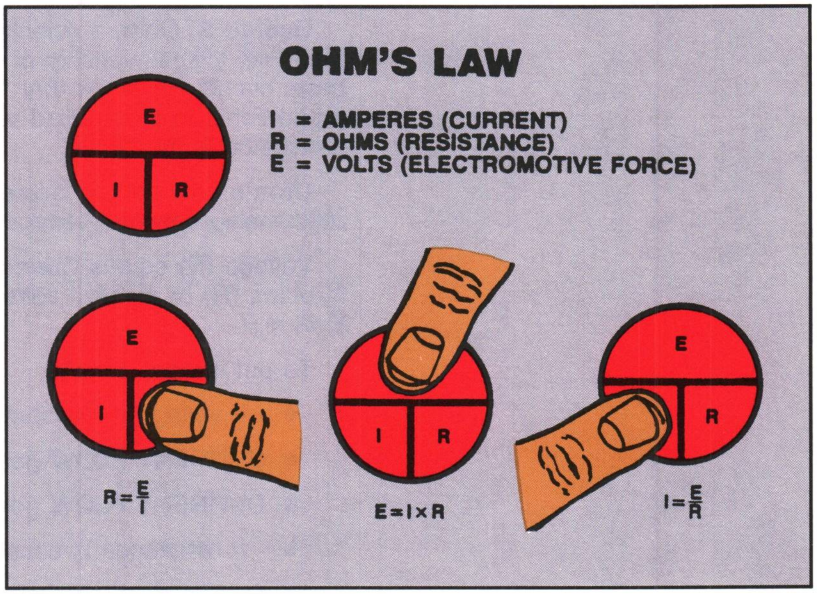
Voltage (E) equals Current Flow in amperes (I) times Resistance in ohms (R) or simply.. volts = amps x ohms or using the symbols $E = I \times R$

To put it more simply:

- - If voltage is constant,
- CURRENT FLOW goes DOWN when RESISTANCE goes UP.
- CURRENT FLOW goes UP when RESISTANCE goes DOWN.
- - If resistance is constant,
- CURRENT FLOW goes UP when VOLTAGE goes UP.
- CURRENT FLOW goes DOWN when VOLTAGE goes DOWN.
- - If current flow is constant,
- VOLTAGE goes UP when RESISTANCE goes UP.
- VOLTAGE goes DOWN when RESISTANCE goes DOWN.

If you know any two of the three items for a given circuit, you can find the missing one. Simply substitute the values for amperes, volts and ohms in the above equation and solve for the missing value. An easy way to remember the basics of Ohm's Law is to use the circle aid.

Figure 22



- covering R = E/I— finds resistance in ohms

- covering E = I x R — finds voltage in volts

- covering I = E/R — finds current in amps

  For example, if you want to find the resistance (R) of a taillight bulb in a circuit that has a current flow of three (3) amps, being pushed by twelve (12) volts.

  Using the circle aid and covering the R you would get the equation:

1. R = E/I

   Substituting the values of voltage and amps gives:

2. R = 12 volts/3 amps

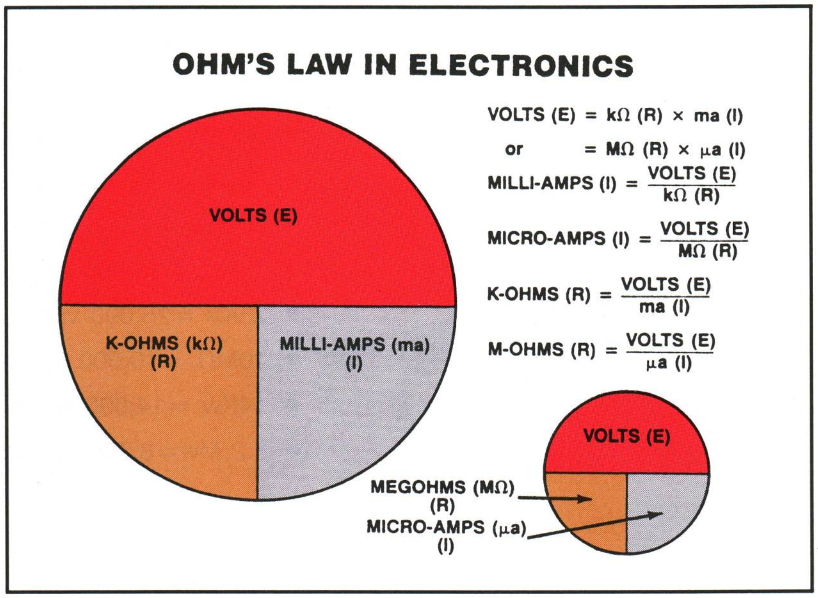
   Performing the division gives the answer:

3. R = 4 ohms

   Resistance of the bulb is 4 ohms.

OHM'S LAW IN ELECTRONIC CIRCUITS

Figure 23



OHM'S LAW IN ELECTRONICS

$$\text{VOLTS (E)} = \text{k}\Omega\ \text{(R)} \times \text{ma (I)}$$

$$\text{or} \quad = \text{M}\Omega\ \text{(R)} \times \mu\text{a (I)}$$

$$\text{MILLI-AMPS (I)} = \frac{\text{VOLTS (E)}}{\text{k}\Omega\ \text{(R)}}$$

$$\text{MICRO-AMPS (I)} = \frac{\text{VOLTS (E)}}{\text{M}\Omega\ \text{(R)}}$$

$$\text{K-OHMS (R)} = \frac{\text{VOLTS (E)}}{\text{ma (I)}}$$

$$\text{M-OHMS (R)} = \frac{\text{VOLTS (E)}}{\mu\text{a (I)}}$$

The principles that apply to Ohm's Law are the same for electronics as for electricity. In electronics, however, the calculations involve higher resistances, resulting in lower amperages.

Quite often we need to show those measurements as very large or very small quantities of electrical units. To do this, the metric system is used.

Two common divisions of units smaller than one (1) are MILLI and MICRO.

Milli is used to indicate thousandths of one, i.e. 0.001 or 1/1000.

Micro is used to indicate millionths of one, i.e. 0.000001 or 1/1,000,000.

The symbol for milli is a lower case **m**, and the symbol for micro is μ.

To indicate large numbers, the units are KILO and MEGA.

- Kilo means times 1000
- Mega means times 1,000,000.

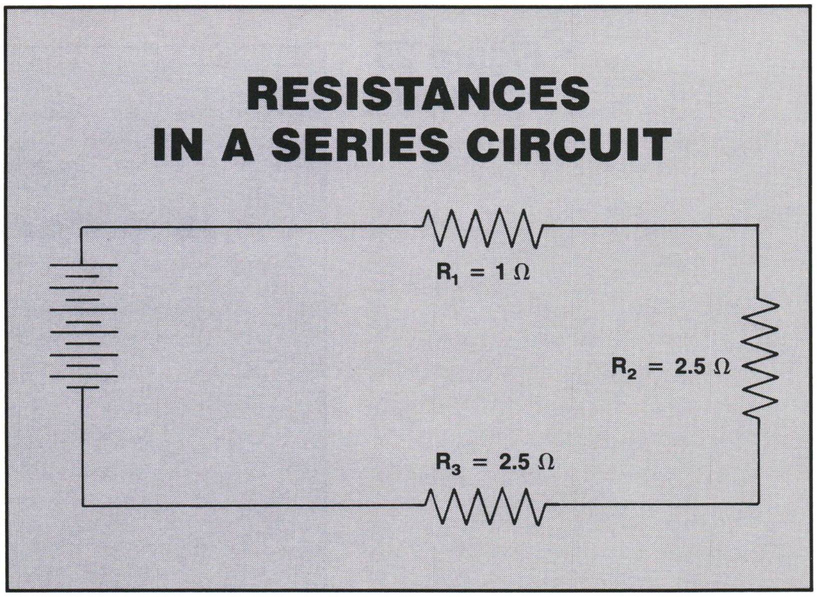
- The symbol for kilo is an uppercase **K**, and the symbol for mega is an uppercase **M**.

Some examples of these units are:

- 15mA =0.015 amps
- 500mA =0.5 amps
- 650mV =0.65 volts
- 50μA =0.000050 amps
- 700μV =0.0007 volts
- 15KΩ =15,000 ohms
- 25Kv =25,000 volts
- 10MΩ =10,000,000 ohms
- 14Kw =14,000 watts
- 8.2 Mw=8,200,000 watts

MEASUREMENTS IN SERIES CIRCUITS

Figure 24



RESISTANCE

Resistances in a series circuit are additive. To determine the total resistance of a circuit, add all the resistances together.

R_t (TOTAL RESISTANCE) $= R_1 + R_2 + R_3$

$R_t = 1.0$ ohm $+ 2.5$ ohm $+ 2.5$ ohm

$R_t = 6.0$ ohms

CURRENT

In a series circuit the same amount of current flows through all of the components in the circuit. Thus if we measure the amperage in a series circuit, it will be the same value for all measurement locations. The value of the amperage is determined using Ohm's Law and is a function of the voltage and the resistance of the circuit.

The current in a series circuit is determined by dividing the power source by the total resistance.

$I = E/R_t$

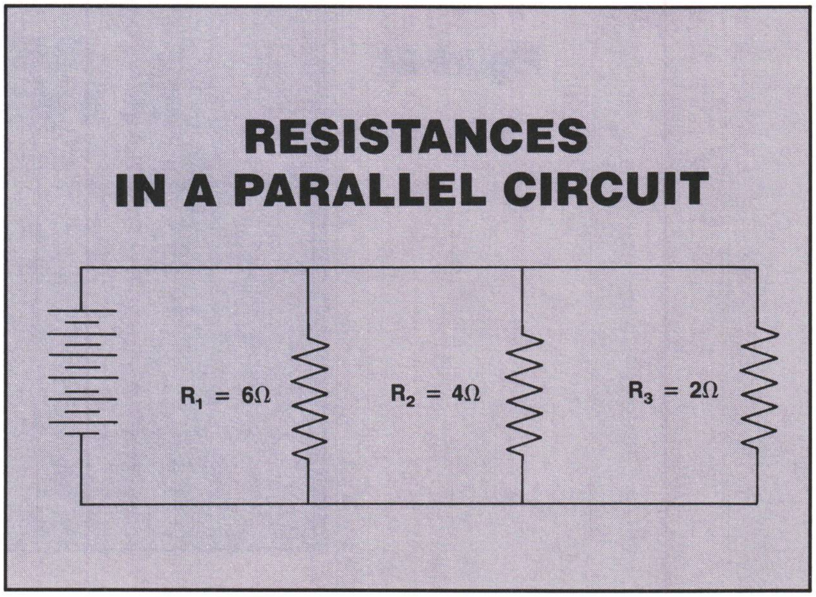
$I = 12$ volts/6.0 ohms $= 2.0$ amps

VOLTAGE

Voltage in a series circuit will change (drop) as the current flows through more resistances (loads) in the circuit.

MEASUREMENTS IN PARALLEL CIRCUITS

Figure 25



RESISTANCES

In a parallel circuit the total resistance of the circuit is less than the value of the smallest resistance. To determine the total resistance of a parallel circuit you can use the assumed voltage method.

Assumed Voltage Method

Step 1 — Assume a voltage for the circuit

Step 2 — Determine the current going to each load

Step 3 — Add the current going to each load to get the total current

Step 4 — Determine the total resistance of the circuit by dividing the assumed voltage by the total current

Example (Refer to Figure 25)

Step 1 — Assumed voltage = 12 volts

Step 2 — Current to R_1 ; $I_1 = \frac{E}{R_1} = \frac{12V}{6\Omega} = 2$ amps

Current to R_2 ; $I_2 = \frac{E}{R_2} = \frac{12V}{4\Omega} = 3$ amps

Current to R_3 ; $I_3 = \frac{E}{R_3} = \frac{12V}{2\Omega} = 6$ amps

Step 3 — 2 amps + 3 amps + 6 amps = 11 amps

Step 4 — $R_T = \frac{E}{I} = \frac{12 \text{ volts}}{11 \text{ amps}} = 1.09\ \Omega$

CURRENT

The current in a parallel circuit is a function of the resistance in each branch of the circuit and the total resistance in the circuit. Each branch of the circuit can be viewed as a separate series circuit having its own total resistance and current. The current in each branch of the circuit will be different if the resistance in the branches are different.

Current in each branch:

- I=E/R=12volts/6 ohms=2 amps (branch 1)
- I=12 volts/ 4 ohms=3 amps (branch 2)
- I=12 volts/ 2 ohms=6 amps (branch3)
The total current in the circuit is determined using the total resistance for the system.

Total current , I=E/R=12 volts/ 1.09 ohms=11.0 amps

VOLTAGE

Voltage into each branch in a parallel circuit is equal to the source voltage.

LESSON AGENDA

LESSON 4: ELECTRICAL COMPONENTS

CONTENT

- Electrical system components
- Operation of electrical components

INSTRUCTOR OBJECTIVES

The instructor will:

- Define the various types of components used in the electrical system
- Explain how components are organized into a system
- Describe what can go wrong with various components

TECHNICIAN OBJECTIVES

The Technician will:

- Identify electrical system components
- Describe the operation of various components in the electrical system
- Assemble components into a working system

LESSON 4 GLOSSARY

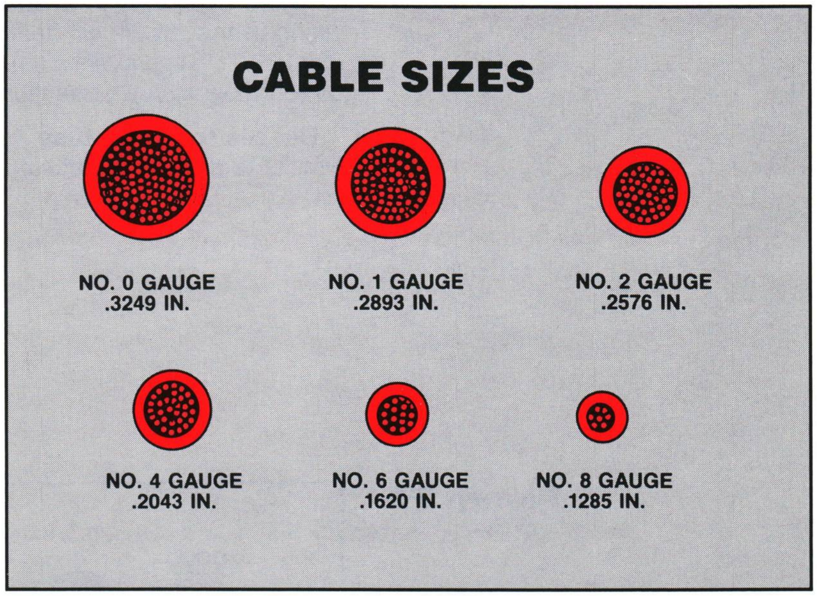
Bi-Metal Strip	Two strips of metal that are bonded together which expand at different rates when heated.
Break Before Make	The wiper of a switch does not close a circuit before it opens the preceding circuit.
Buss	Point of power distribution.
Circuit Breaker	Device which protects circuit from overload.
Cycling Circuit Breaker	Circuit protection device which opens a circuit when an overload occurs and makes the circuit when overload ceases.
Fixed Value Resistors	Resistor having a specific value of resistance.
Flasher	A time delay switch that opens after a predetermined time, but closes and then reopens, continuing the cycle until the power is removed.
Fuse	A protective device placed in a circuit which will melt and discontinue current flow if an overload condition exits.
Fuse Block	Location of fuses and power to circuits.
Fuse Link	A protective device placed in a circuit which will melt and discontinue current flow if an overload condition exists.
Ganged Switch	A switch having two or more wipers that operate in unison from a single control.
Gauge	Size of a conductor wire.
Hinged Pawl Switch	Makes or breaks the current in a single conductor or circuit.
Make Before Break	The wiper of the switch closes a circuit before it opens the preceding circuit.
Mercury Switch	Contains a capsule partially filled with mercury which makes or brakes contacts when switch is tipped.
Momentary Contact Switch	Has a spring-loaded contact that keeps it from making (or breaking) the circuit except when pressure is applied to the button.
Non-Cycling Circuit Breaker	Circuit protection device which opens a circuit when an overload occurs. Power must be removed to reset the breaker.
Normally Closed	When the rest position of the switch is to close the circuit.
Normally Open	When the rest position of the switch is to open the circuit.
Potentiometer.	A type of variable resistor.
Relay	Switch that uses a small current flow to control a larger current.
Resistors	Devices used to limit current flow in a circuit due to their high resistance to current flow.
Resistor Wires	Wire having a high resistance to current flow. Rated in ohms per foot.
Rheostats	A type of variable resistor.
Solenoids	Electromagnets with movable cores which are used to translate electrical current flow into mechanical movement.
Stepped Resistors	Have two or more fixed resistance values, which can be selected by connecting wires to the various taps on the resistor.

LESSON 4 GLOSSARY

Switches	Off-on controls in a circuit.
Temperature-Sensitive Switch	Contains a bi-metal element which makes or breaks a circuit when the switch is heated.
Thermal Limiter	Temperature sensitive device which protects circuit from overload.
Time Delay Switch	Opens after a predetermined time, and stays open as long as the power is applied to the switch.
Variable Resistors	Have a range of resistances available through two or more taps and a movable control.
Wiper	Movable portion in a variable resistor or switch.
Wiring Harness	Bundle of wires wrapped together for consolidation purposes.
Wiring Loom	Another name for a wiring harness.

CONDUCTORS

Figure 26



Conductors carry electric current to and from the components in the circuit. Most are made from copper and are insulated with non-conductive coverings that are temperature and corrosion resistant. The amount of current a conductor can carry is dependent on it's size. In automobiles, wire sizes from No. 0 **gauge** to a No. 20 gauge are used.

Each circuit in the vehicle is assigned a circuit number and each conductor is assigned a wire color. Wires colors can be solid, striped, dotted or hashed. In wiring diagrams, the circuit number is shown first, followed by the color code. Thus 57 BK would mean circuit 57 and black wire.

Additional information about wire coding will be covered later.

WIRING HARNESSES

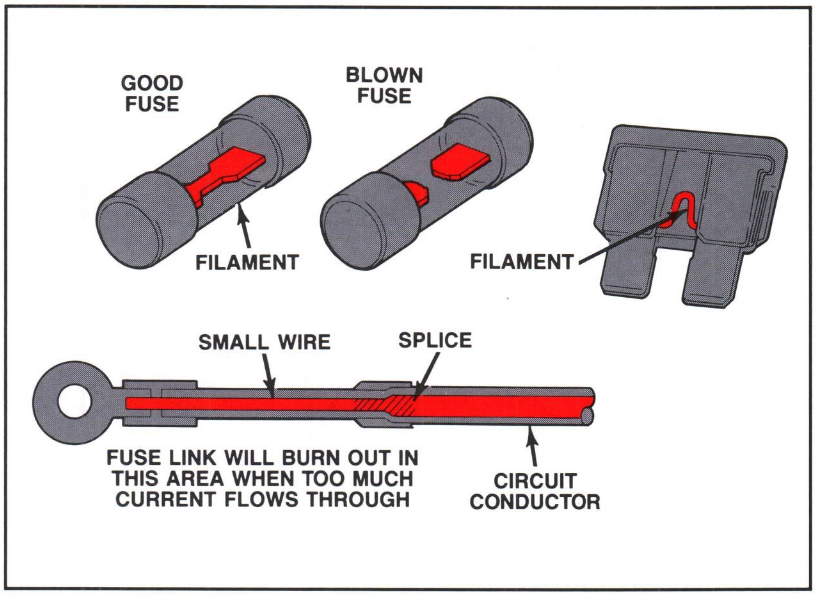
The **wiring harness** is the consolidation points of all the wiring in the vehicle. In some publications, you may also see the wiring harness referred to as a **wiring loom**. Harnesses generally connect components in one area of the vehicle to another. This method simplifies assembly of the vehicle and provides greater flexibility in the addition of accessories to the vehicle.

CIRCUIT PROTECTION

When overloads in a circuit cause too much current to flow, the wiring in the circuit will heat up, the insulation may melt, and a fire may result. To prevent damage to the circuit due to excessive current flow circuit protection devices are used.

Devices such as a **fuse, fuse link,** or **circuit breaker** are designed into circuits to provide protection from overloads.

Figure 27


GOOD FUSE
BLOWN FUSE
FILAMENT
FILAMENT
SMALL WIRE
SPLICE
FUSE LINK WILL BURN OUT IN THIS AREA WHEN TOO MUCH CURRENT FLOWS THROUGH
CIRCUIT CONDUCTOR

FUSES

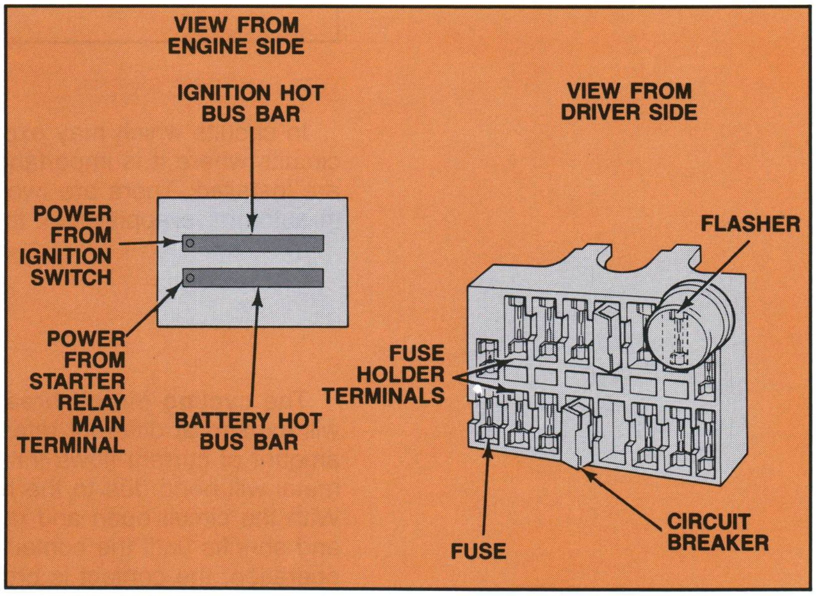
Fuses are the type of protection devices generally used in automobile electrical systems. The conductive element of a fuse is usually a lead alloy material which will provide excellent current carrying ability within it's rating. If an excessive amount of current flows through the circuit, the fuse element melts and opens the circuit, thus eliminating current flow to the circuit and preventing damage to the components.

Fuses are designed to carry a specific amount of current. If current flow exceeds the design limit, the fuse will open (blow) and disable the circuit. If you examine a fuse closely, you will notice that the conductive element is smaller in size than the circuit it protects. The maximum amperage rating of each fuse is marked on the fuse. The newer bayonet style fuses are color-coded (all 10-amp fuses are red, etc.). The glass tube type fuses come in three different lengths (for automotive type fuses). Usually, the longer the fuse, the higher the amperage rating. When a fuse opens, it should always be replaced with a fuse of the same amperage rating - NEVER with a fuse of higher rating. Generally, the fuse assigned to protect a circuit will be rated well above the normal current flow for that circuit. This allows for normal variations in the circuit.

FUSE BLOCK

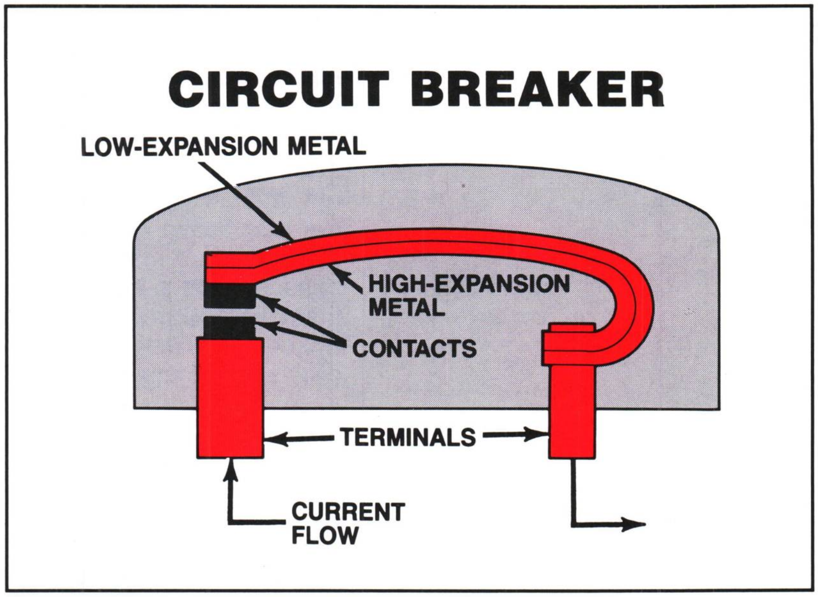
Fuse blocks are normally located under the instrument panel to the left of the steering column, and are designed to hold fuses and to supply power to many circuits.

Figure 28



In modern vehicles, the fuse block is arranged with circuits that are powered directly from the battery, and others that are controlled by the ignition switch. To reduce the number of wires at the fuse block, a single battery circuit and a single ignition circuit may be connected to a **buss** to distribute power to numerous systems through several fuses.

Figure 29



CIRCUIT BREAKERS

In circuits which may experience temporary overloads, and in circuits where it is important to restore power quickly, circuit breakers are installed. There are two types of circuit breakers generally used in automotive application, the cycling type and the non-cycling type.

The **cycling circuit breaker** consists of a **bi-metal strip** which will expand at different rates when heated. When an excessive amount of current flows through the bimetal strip, the high-expansion metal will bend due to the heat build-up and open the contact points. With the circuit open and no current flowing, the bi-metal strip cools and shrinks until the contact points again close the circuit. In actual operation, the contact is broken very quickly. If the overload is continuous, the circuit will be repeatedly broken and made until the source of the problem is corrected. This type of circuit breaker is the type generally used in automotive electrical systems.

In the **non-cycling circuit breaker**, a wire coil is wrapped around the bi-metal arm that maintains a high-resistance current path in the circuit after the contact points open. The heat from the wire coil will not allow the bi-metal strip to cool enough to close the contact points until power is removed from the circuit. Once power is removed, the strip will cool and the circuit will be restored. This type of circuit breaker is used in circuits like the power seats or power door locks which remain powered when the ignition is off.

FUSE LINK

A fuse link is a short length of wire, normally four gauge sizes smaller than the circuit wiring, and made of a copper alloy that has a lower melting point than normal copper wire of the same size. The fuse link is installed close to the power source, and generally is used to protect large portions of the vehicle wiring when fuses or circuit breakers would not be practical. Because the fuse link is a lighter gauge wire than the conductor wire, if an overload occurs, the fuse link will melt and open the circuit before damage to the rest of the circuit can take place. Fuse link wire is covered with heat-resistant, non-flammable insulation which bubbles when the fuse link melts, indicating the fuse link is open and must be replaced.

To replace a fuse link, cut the conductor at the fuse link splice splice in a new fuse link and crimp it on with a butt connector.

THERMAL LIMITERS

Thermal Limiters are used in circuits where current flow may not be a good indicator of a problem in the system. A thermal limiter is designed to be sensitive to the temperature of the components around it. When the temperature reaches a specific point, the conductive material will melt and disable the circuit. Most current A/C blower circuits are equipped with thermal limiters that will completely or partially disable the blower motor if there is not enough airflow in the blower case to keep the blower motor resistor cool. If the thermal limiter fails, the entire blower resistor assembly must be replaced.

CLASS SESSION

CONTROLLING DEVICES

Not all items in the electrical system require the same power. Controlling devices are used to limit or control the flow of current within the circuits.

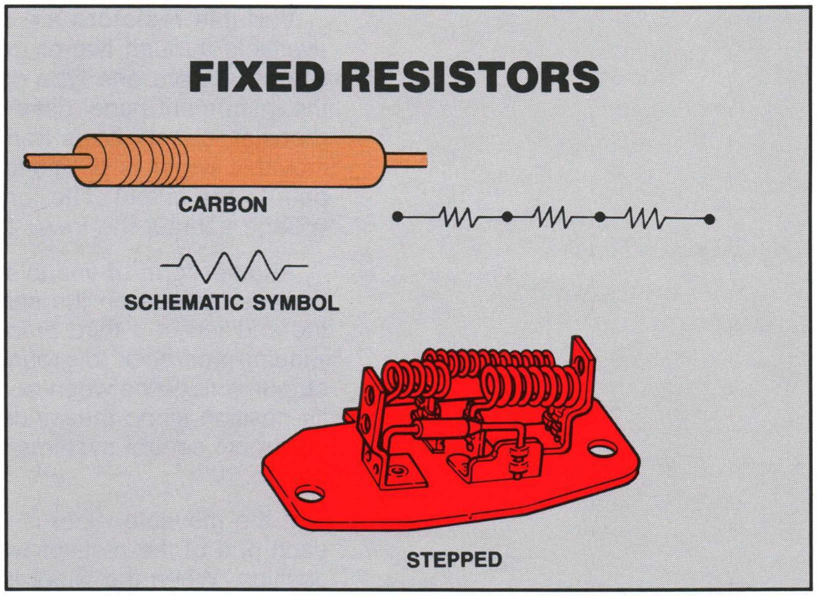
RESISTORS

Resistors are used to limit current flow in circuits where full current flow and/or voltage is not needed. Resistors create a voltage drop and dissipate the power in the form of heat. The heat producing feature of resistors is used in applications such as an electric window defroster, electric choke cap heater, and electric cigar lighter. The filaments in electric lamps produce heat, but the lamps are primarily used for illumination.

There are three types of resistors used in automotive circuits:

- Fixed value resistors
- Stepped or tapped resistors
- Variable resistors

Figure 30



FIXED RESISTORS

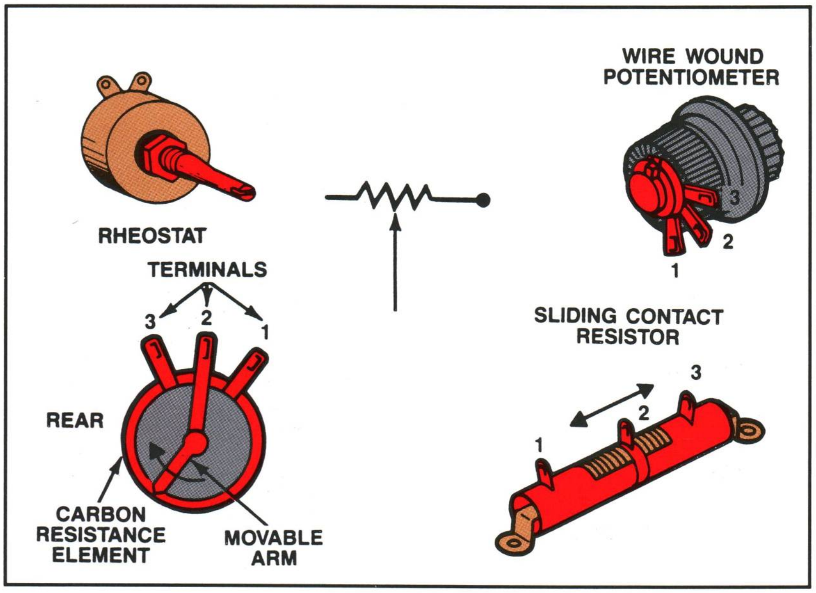
Fixed value resistors are designed to have a specific value and are rated in ohms. They are used to reduce the source voltage in a circuit or to limit current flow. A fixed value resistor may be built into a component or installed in-line, depending on the application.

STEPPED RESISTORS

Stepped resistors have two or more fixed values, which can be selected by connecting wires to the various taps on the resistor. Blower motor resistor packs are an example of this type of resistor. By selecting different switch positions on the control panel, resistors are added or subtracted in series to increase or decrease current flow to the blower motor.

VARIABLE RESISTORS

Figure 31



Variable resistors are designed to have a range of resistances available through two or more taps and a movable control. **Rheostats** are one type of variable resistor. A typical application are the instrument panel dimmer control and radio volume control. In a rheostat, current flows from the power source through a winding. A movable **wiper** is positioned against the winding and completes the path to the output. The further the wiper is moved away from the voltage source, the lower the output voltage becomes.

Another form of variable resistor is the **potentiometer**. These devices operate on the same basic principal as a rheostat except for the addition of a third branch. Current flows through the resistor winding and back to ground. The movable wiper will produce an output voltage between source voltage and zero volts depending on its position along the winding. This application is used frequently in electronic control systems to measure the movement of a mechanical device.

If the movable wiper is used as the voltage source, the output at each end of the resistor winding will vary depending on the wiper position. When the wiper is centered, output will be equal at both ends. When the wiper is moved, voltage will be highest at the output closest to the wiper. This application of a potentiometer is used as a balance control for stereo radios.

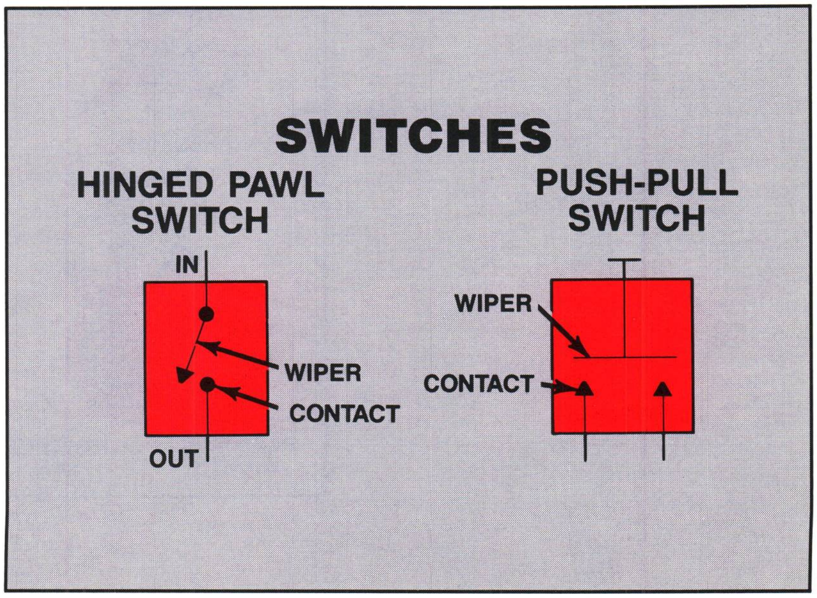
RESISTOR WIRES

Resistor wires are used to deliver a predetermined voltage to a given load. They are rated in ohms per foot and therefore the length of the wires is extremely important to the overall operation of the system. As the current flows through the wire, the voltage will drop because of the internal resistance of the wire. This voltage drop can be detected and a predetermined action will occur. A typical application is the Lamp Out Warning System.

CAUTION: Resistance wires, like fuse links, are also spliced into conductors in some areas. Do not make the mistake of replacing a fuse link with a resistance wire. Resistance wires are usually longer than fuse links and are marked "RESISTOR - DO NOT CUT OR SPLICE."

SWITCHES

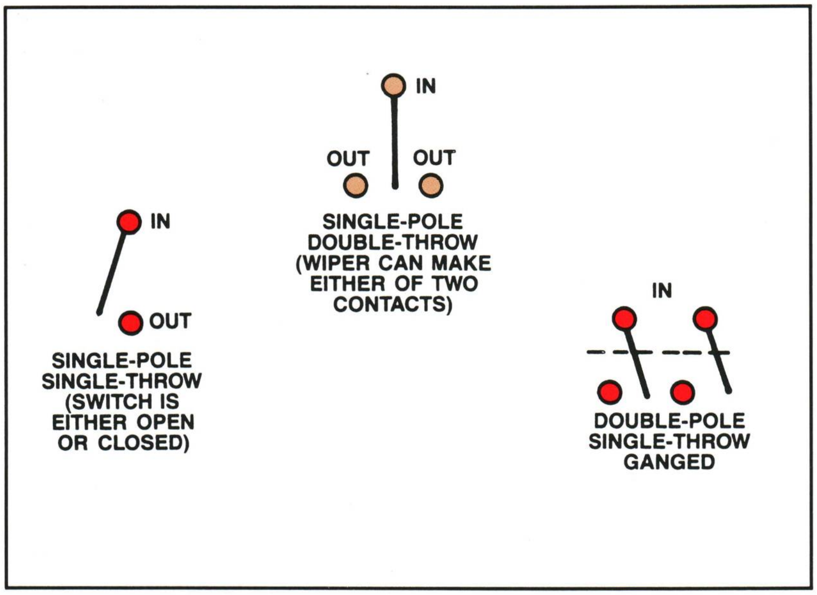
Figure 32



Switches are off-on controls in a circuit, that is they open or close the circuit. Switches may be manually controlled or self-operating through a condition of the circuit or vehicle. They can be **normally open** or **normally closed**. Normally open means the usual or rest position of the switch is to open the circuit. Normally closed means the usual or rest position of the switch is to close the circuit.

Switches have one or more poles (inputs) and throws (outputs). A single pole double throw switch would have one input and two outputs.

Figure 33


IN
OUT
OUT
SINGLE-POLE DOUBLE-THROW (WIPER CAN MAKE EITHER OF TWO CONTACTS)
IN
OUT
SINGLE-POLE SINGLE-THROW (SWITCH IS EITHER OPEN OR CLOSED)
IN
DOUBLE-POLE SINGLE-THROW GANGED

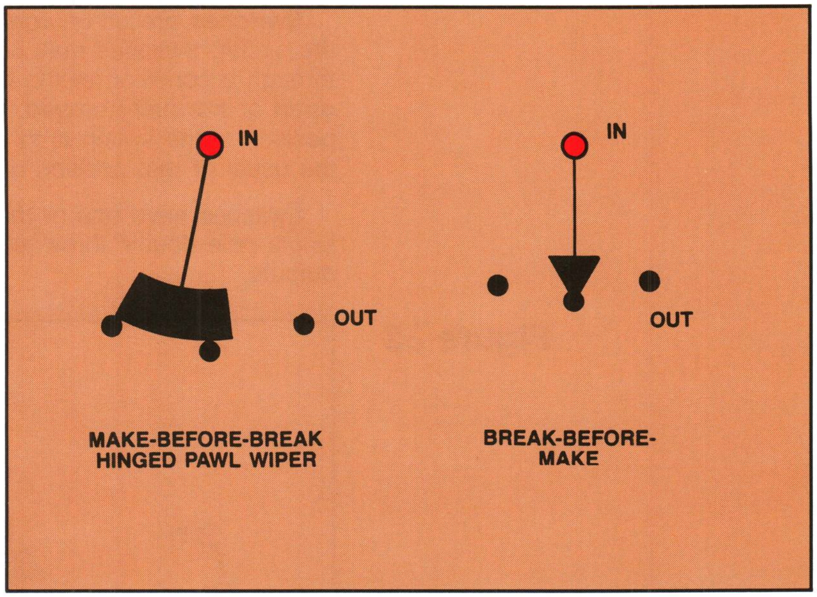
The transmission neutral-start switch has two poles and six throws, and is referred to as a multiple-throw, multiple-pole switch. Two wipers move in unison across two sets of poles (they are ganged together). The switch closes a circuit to the starter in either P (Park) or N (Neutral), and to the backup lights in R (Reverse).

In multiple throw switches there is a MAKE-BREAK sequence. It can be either **make before break** or **break before make**.

In a make before break type switch, the wiper of the switch closes a circuit before it opens the preceding circuit. The ignition switch is an example of a make before break.

In a break before make type switch, the wiper of the switch does not close a circuit before it opens the preceding circuit.

Figure 34



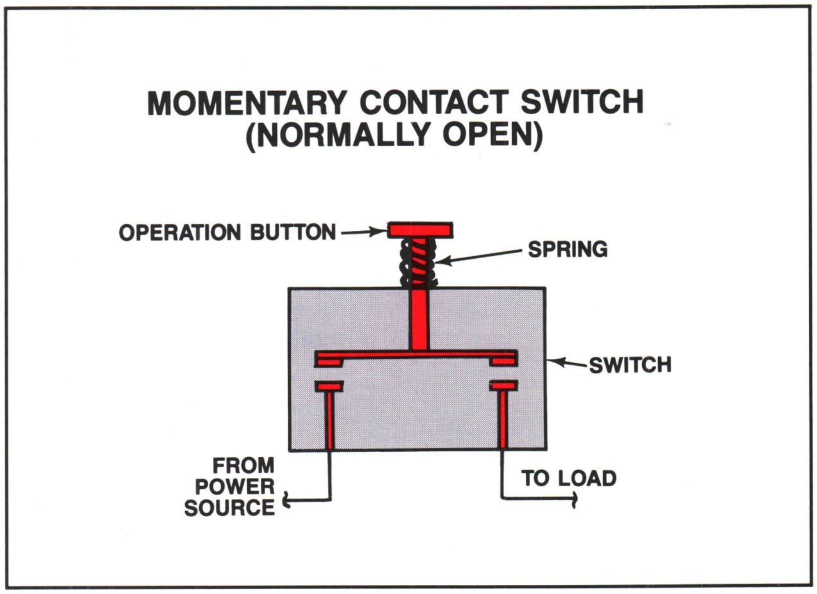
If a switch has two or more wipers that operate in unison from a single control it is referred to as a **ganged switch**.

HINGED PAWL

A **hinged pawl switch** is the simplest type of switch. It either makes or breaks the current in a single conductor or circuit. The hinged pawl can be a single-pole, single-throw switch or a single-pole double-throw switch. Single-pole, double-throw switches have one wire in and two wires out. A single-pole double-throw switch feeds either the high-beam or low-beam headlight circuit.

MOMENTARY CONTACT

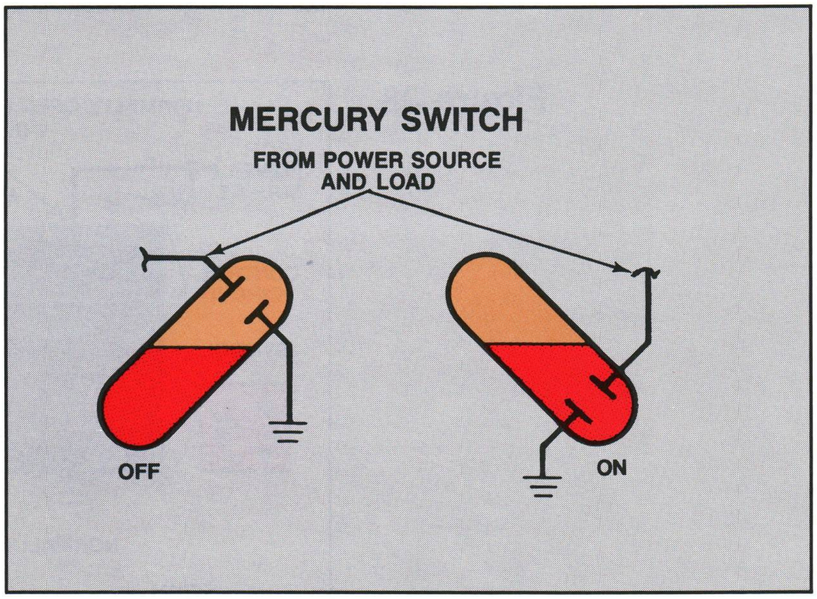
Figure 35



The **momentary contact switch** has a spring-loaded contact that keeps it from making the circuit except when pressure is applied to the button. This is a normally open type. If the spring holds the contacts closed except when the button is pressed, it is a normally closed type.

MERCURY SWITCH

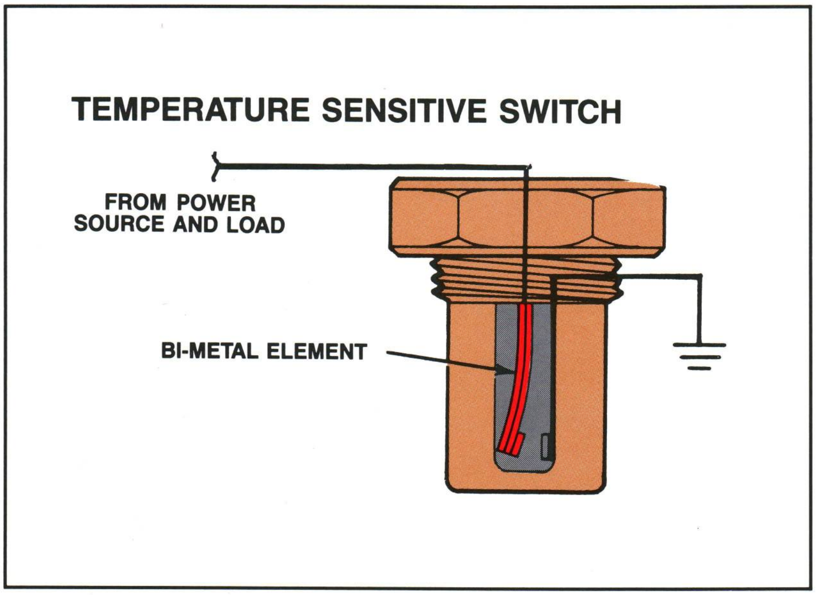
Figure 36



A **mercury switch** is used to detect motion in a component, such as the one used in the engine compartment or the luggage compartment to turn on the light. Inside the switch, a capsule is partially filled with mercury. In one end are two electrical contacts. As the lid is opened, the mercury flows to the opposite end of the capsule with the contacts, completing the circuit for the light.

TEMPERATURE SENSITIVE SWITCH

Figure 37



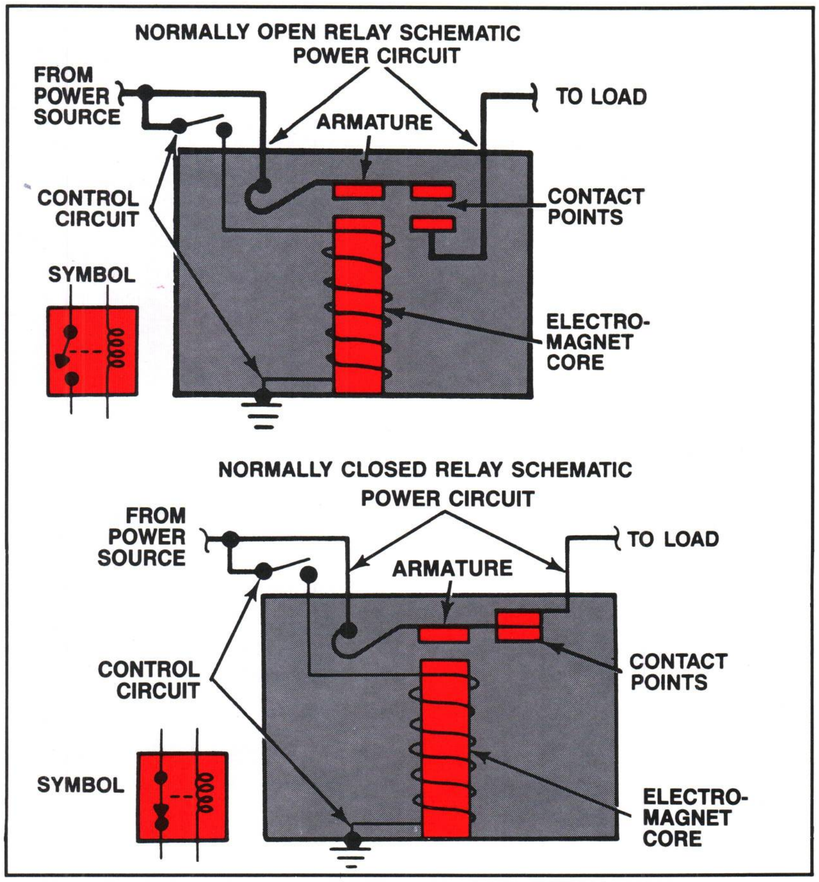
A **temperature-sensitive switch** usually contains a bimetal element heated either electrically or by some component where the switch is used as a sensor.

In an engine coolant temperature switch, when the coolant reaches the temperature limit, the bimetal element bends causing the contacts in the switch to close. This completes the circuit and lights the warning indicator on the instrument panel.

Heat-sensitive switches are also used as time delay switches and flashers, and in circuits such as the rear window defroster.

RELAYS

Figure 38



A **relay** is an electric switch that uses a small current flow to control a larger current.

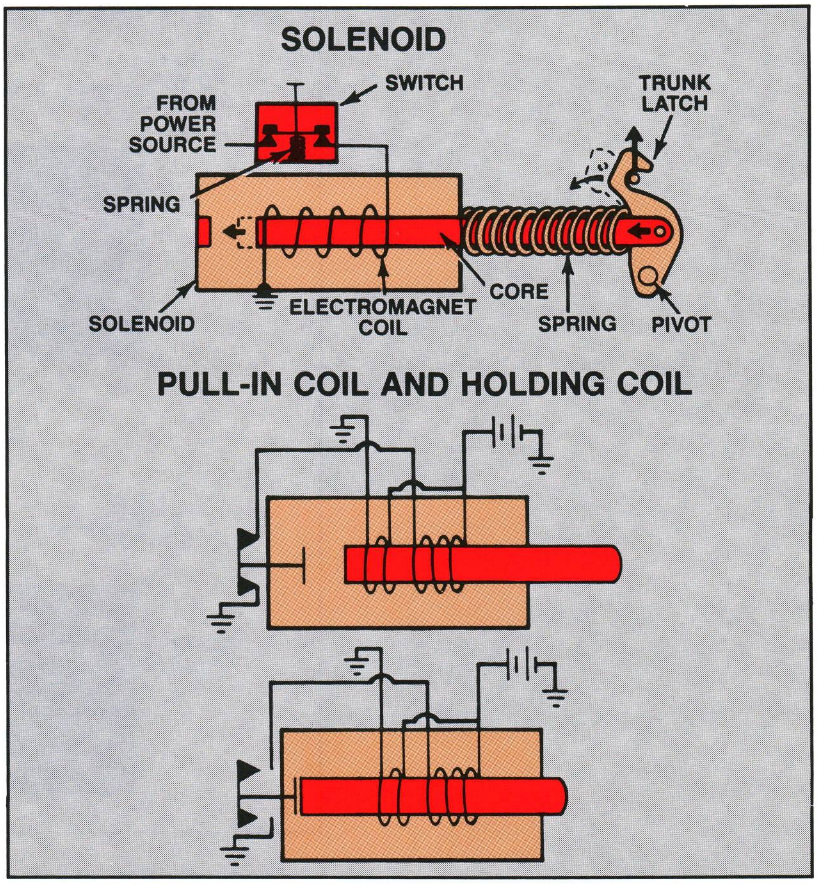
A relay consists of a control circuit, an electromagnet, an armature and a set of contacts. When current is applied to the control circuit, the electromagnet is energized and pulls the armature towards it. Contacts mounted on the armature are either opened or closed by the movement of the armature. The opening and closing of the contacts makes or breaks the circuit to the load being controlled.

When the control circuit switch is open, no current flows to the relay coil, the electromagnet is de-energized and the armature returns to the rest position.

Typical applications are fuel pump relay, horn relay and starter relay.

SOLENOIDS

Figure 39



Solenoids are electromagnets with movable cores which are used to translate electrical current flow into mechanical movement. They may also close contacts, thus acting as a relay at the same time.

A typical solenoid application is in the luggage compartment. Pressing the momentary contact switch on the instrument panel energizes the solenoid coil, and magnetic force pulls the solenoid core. The latch, connected to the core, releases the luggage compartment lid. Releasing the dash switch stops current flow in the solenoid circuit and the spring resets the latch in a closed position.

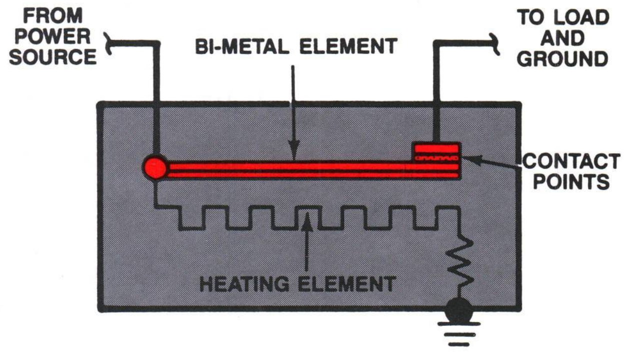
NOTE: Relays and solenoids are often confused. Remember that solenoids produce a mechanical output, while relays produce an electrical output.

TIME DELAY SWITCHES AND FLASHERS

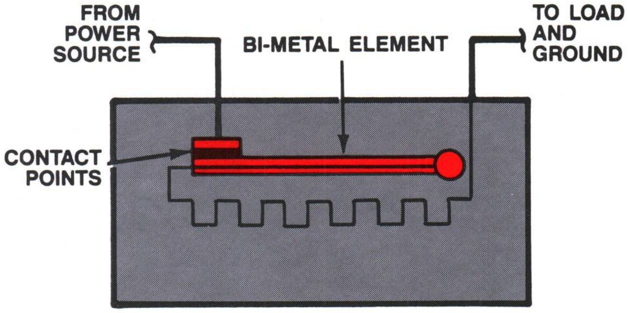
A **Time Delay Switch** opens after a predetermined time, and stays open as long as the power is applied to the switch. A **flasher** is a time delay switch that opens after a predetermined time, but closes and then reopens, continuing the cycle until the power is removed.

Figure 40

TEMPERATURE SENSITIVE TIME DELAY SWITCH



FLASHER



The time delay switch contains a bi-metal strip, contacts and a heating element. The time delay switch is normally closed. As current flows through the switch, some current flows through the heating element causing it to heat which causes the bimetal strip to bend and open the contacts. As long as current is flowing through the heating element the switch remains open. The time delay before the contacts open is determined by the characteristics of the bimetal strip and the amount of heat produced by the heating element. When power to the switch is turned off, the heating element cools and the bimetal strip returns to the rest position and the contacts are closed. Typical application is the control circuit to the rear window defroster.

The flasher operates basically the same as the time delay switch, except when the contacts are open, the power to the heating element is eliminated, causing the heating element to cool. The bimetal strip returns to the rest position and closes the contacts. The cycle starts over again and will continue to cycle until power to the flasher is eliminated. A typical application for this type of switch is to operate the four-way flashers.

BUZZERS

Mechanical buzzers are similar to relays in that they use an electromagnet to open and close contacts. The difference is in the internal connectors. When the switch to the buzzer is closed, current flows through the contacts and into the coil. The magnetized core attracts the armature, breaking the operating contacts. This breaks the pull on the coil and the spring-loaded arm. The armature returns to the rest position and the contacts close and the coil is energized once more, thus the cycle is repeated until the switch to the buzzer is opened. The armature cycles many times a second generating a buzzing sound.

DIODES

Diodes allow current flow in one direction in a circuit, but block current flow in the opposite direction. Diodes are used to create logic circuits. Logic circuits only function if conditions occur in a certain sequence. An example would be to sound the warning buzzer if the key is in the ignition, ignition is in the off position, and the door is opened.

CAPACITORS

Capacitors are used to absorb or store electrical current. The capacitor is composed of two or more conducting plates with non-conducting material between them. Direct current cannot flow through a capacitor but alternating current can. The slight flow of direct current that does occur is useful in soaking up stray currents and preventing arcing across opening contacts.

COILS

A coil is a voltage step-up transformer that is used to raise the vehicle voltage. In the ignition coil the voltage is raised upwards of 50,000 volts to jump the spark plug gap. The coil has a primary and secondary winding on a common core with a common terminal at one end of the windings. In the ignition coil when the primary windings are energized, a magnetic field builds up around the primary and secondary windings and is reinforced by the core. When the primary circuit shuts off current to the coil, the field quickly collapses, inducing a High Tension Current into the secondary winding, through the high tension lead to the distributor cap and out to the appropriate spark plug.

SEALED COMPONENTS

Sealed electronic components require specialized equipment for service. They have been sealed at the factory and generally the seal reads “FOR AUTHORIZED ENTRY ONLY.” Such modules are found in the electronic engine control system and the instrument panel module.

LESSON 5: SERVICE PUBLICATIONS

CONTENT

- Shop Manuals
- EVTMs
- Technical Service Bulletins
- Wiring Diagrams
- Specifications Book

INSTRUCTOR OBJECTIVES

The instructor will:

- Identify the sources of electrical documentation.
- Explain how to use available electrical documentation.
- Direct hands-on practice in using available electrical documentation.

TECHNICIAN OBJECTIVES

The technician will:

- Identify the sources of electrical information available to help him do his job better.
- Locate information in the service literature based upon his need.
- Demonstrate the ability to use service literature while working on a vehicle.

LESSON 5 GLOSSARY

Case Grounds	Used when the component has a metal case and is attached to a well grounded part of the vehicle.
Cut Wire References	Used in EVTM wiring diagrams to show current flow from power to ground.
EVTM	Electrical and Vacuum Troubleshooting Manual - Contains electrical and vacuum systems drawn in a clear and simple way to make troubleshooting easier.
OASIS	On-line Automotive Service Information System - A computer based service information system designed to assist service technicians with difficult vehicle diagnosis and repair problems.
Reference Wires	Reference wires are used in EVTM wiring diagrams to complete wiring shown on another page of the wiring diagrams.
Remote Grounds	Remote grounds are used where the component itself is not grounded and is shown in the wiring on the wiring diagram.
Shop Manual	Provides information covering normal service, repairs and maintenance for multiple vehicle lines. The information is very detailed and is the best initial source of information.
Specification Book	Contains service specifications for all vehicle lines.
TSB	Technical Service Bulletin - Provides the latest service information, clarification of information, information not available at the time manuals were published, revised service procedures, customer problems and more. TSBs are published twice a month.
TSB Index	Technical Service Bulletin Index - Provides a quick and easy way of finding necessary technical service bulletin information.
Wiring Diagrams	Wiring diagrams present the wiring schematics for the complete vehicle.

INFORMATION SOURCES

There are various manuals and books that contain information to aid the Service Technician in the diagnosis and correcting of service problems. It is important that the Service Technician be familiar with them and know the purpose of each source, what information it contains and how to find the information. The technician must be able to understand the information and apply it to the diagnosis and solution of service problems. Knowing which source to use and when to use it will make your job much easier. These books should be considered as tools, just as a DVOM or a TEST LIGHT. As you become more knowledgeable in finding and using the information contained in these sources, you will become a better Service Technician.

During this lesson we will discuss each source, it's purpose, the information it contains, and how to use it. The sources to be discussed are:

- SHOP MANUALS
- EVTMs
- SPECIFICATIONS BOOK
- TECHNICAL SERVICE BULLETIN INDEX
- TECHNICAL SERVICE BULLETIN
- WIRING DIAGRAMS
- OASIS

The above items are given in a recommended priority of use. For example: **Shop Manuals** should be used first to find information, **EVTMs** the second choice and so on.

Some of the sources have more current information than others. Listing them in order of the most current information would look like this.

- OASIS
- TECHNICAL SERVICE BULLETINS
- EVTMs
- WIRING DIAGRAMS
- SHOP MANUALS
- SPECIFICATIONS BOOK

Be aware that some books contain information for "all" vehicle lines, while others contain information of "multiple" lines and others contain information for a "single" vehicle line. There is a book for each model year. It is important that the Service Technician use the right manual for the vehicle line and model year on which he is working.

SHOP MANUAL

PURPOSE OF SHOP MANUALS

Shop manuals provide information covering normal service, repairs, and maintenance for multiple vehicle lines. The information contained in the Shop Manuals is very detailed and by it's intended use (service and repair) is the best source of information to start with. In the vast majority of cases, it will be the only source of information you will need.

Shop Manuals cover four areas:

- Body, Chassis, Electrical
- Powertrain, Lubrication, Maintenance
- Pre-Delivery
- Engine/Emissions Diagnosis

In this lesson we are concerned only with the Body, Chassis, Electrical systems Shop Manual.

INFORMATION CONTAINED IN SHOP MANUALS

Each section of the Shop Manual contains the following information:

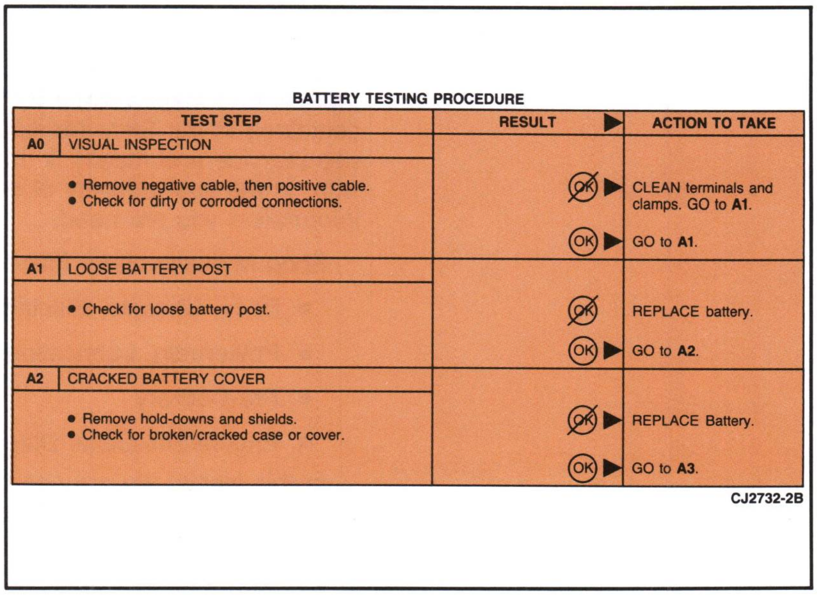
Vehicle Application defines the vehicles to which the section applies.

A short Description and Operation of the system is given to orient the user. Often system schematics and system components will be shown.

Adjustments is primarily used for mechanical systems.

Testing information is the real benefit of using the Shop Manual. The Testing Section contains a variety of tests that can be performed on the system or component. Each test is discussed in great detail. A three column chart is used in most instances. It lists the Test Step, Result, and Action To Take. How to perform the test, expected values and results are given. Illustrations showing the component, connector, terminals and location for the test leads are often included to assist the technician in performing the test.

Figure 41



BATTERY TESTING PROCEDURE

TEST STEP		RESULT ▶	ACTION TO TAKE
A0	VISUAL INSPECTION		
	• Remove negative cable, then positive cable. • Check for dirty or corroded connections.	~~OK~~ ▶	CLEAN terminals and clamps. GO to **A1**.
		OK ▶	GO to **A1**.
A1	LOOSE BATTERY POST		
	• Check for loose battery post.	~~OK~~	REPLACE battery.
		OK ▶	GO to **A2**.
A2	CRACKED BATTERY COVER		
	• Remove hold-downs and shields. • Check for broken/cracked case or cover.	~~OK~~ ▶	REPLACE Battery.
		OK ▶	GO to **A3**.

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Diagnosis is another real benefit of using the Shop Manuals. Diagnosis includes conditions, possible sources and actions to take to solve the problem. Some sections have a step by step procedure that will lead you through the troubleshooting process to a solution based upon test results.

Special Service Tools required to perform the tests or service are listed here.

Instructions that aid in the Removal and Installation of the various components as well as their Disassembly and Assembly is given in excellent detail. Information on Servicing and Maintenance, if required, is provided.

HOW TO USE THE SHOP MANUAL

The cover of each Shop Manual lists the Model Year, the Volume and the Area covered, the Vehicle Lines included in the manual and an Index of the contents in alphabetical order and the Group Number of each item. This information should be used to insure you have the proper Shop Manual for the vehicle line on which you are working.

A Cross Reference Index is included in the front of the manual which lists all Manual Numbers, their Content, and the Vehicle Lines covered. This enables you to pick up any shop manual and by using this index, determine which volume of Shop Manual you need for the specific vehicle and area you are working on.

The Table of Contents lists the items contained in the manual by group order. There are reference marks next to the group number of each item, these correspond with reference marks in the body of the manual and are for ease of locating that particular group.

The body of the manual is arranged in order of Group and Section number.

Within the manual, each Group has an index listing the Section Title and page for each section within the group. The page format is by Group-Section-Page, i.e. 31-01-1 (Group 31, Section 01, Page 1)

Each Section also has it's own contents.

To find something in the Shop Manual, first verify you have the correct Shop Manual for the model year and vehicle line on which you are working. Find the item using either the index on the cover or in the table of contents to identify the Group. Go to that group and identify the Section, then go to the section to identify the page number.

EVTM

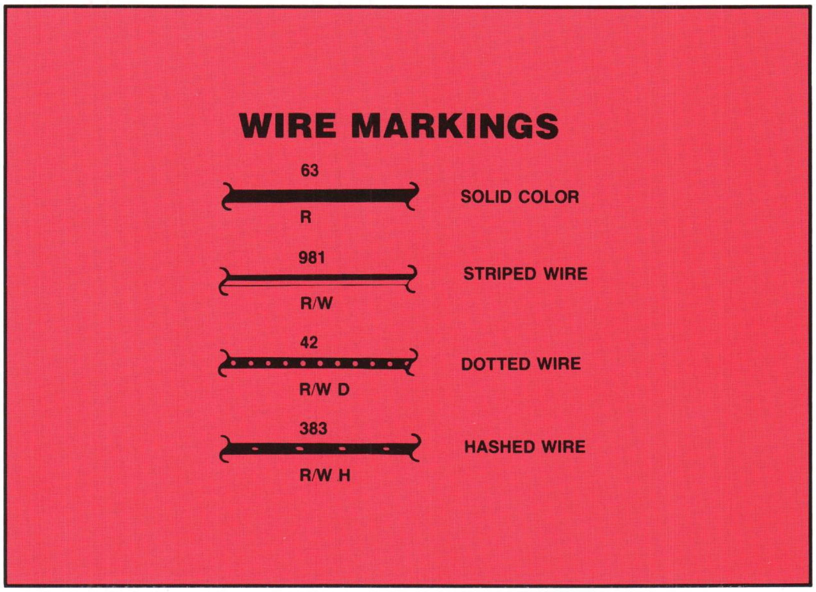
The purpose of the Electrical and Vacuum Troubleshooting Manual or **EVTM** for short, is to show electrical and vacuum systems in a clear and simple fashion to make troubleshooting easier. It is an excellent place to identify where the component is located on the vehicle, find circuit numbers and wire colors. There is an EVTM for each car line by model year. The proper EVTM for the model year and car line must be used to correctly diagnosis and analyze the problem.

INFORMATION CONTAINED IN THE EVTM

For each system or subsystem in the EVTM, there is a schematic of the system, a description of how the circuit works, component listings, location of components and troubleshooting hints.

Wiring diagrams give a schematic picture of when and how the circuit is powered, what the current path is to the circuit components, and how the component is grounded.

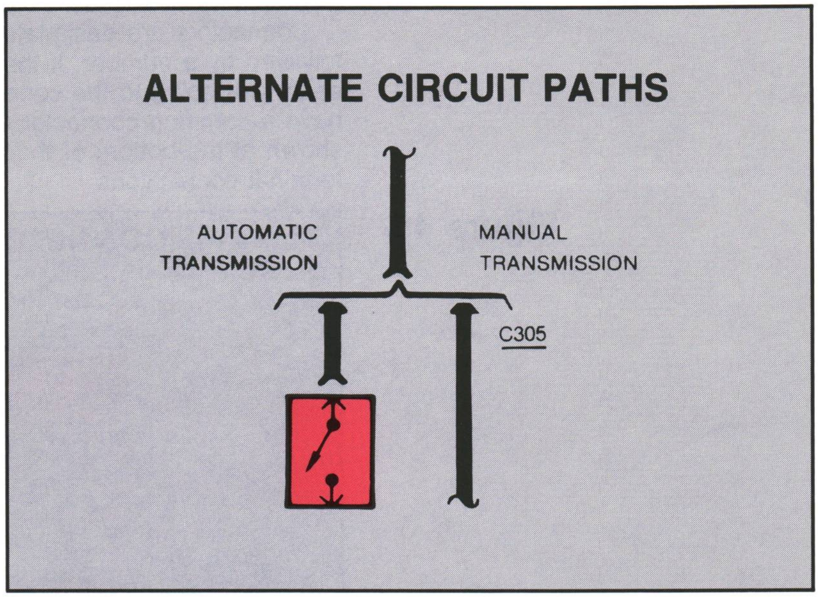
Each circuit component is named, each circuit is assigned a number, and each conductor is assigned a wire color. Standard Ford color abbreviations are used. Where two colors are shown for a wire, the first color is the basic color of the wire. The second color is the stripe, dot, or hash marking.



Circuit descriptions provide a practical explanation of the operation of the system and the components within the system or circuit. There is sufficient detail to enable the reader to obtain a good understanding of the system or circuit and also the operation of the components within it.

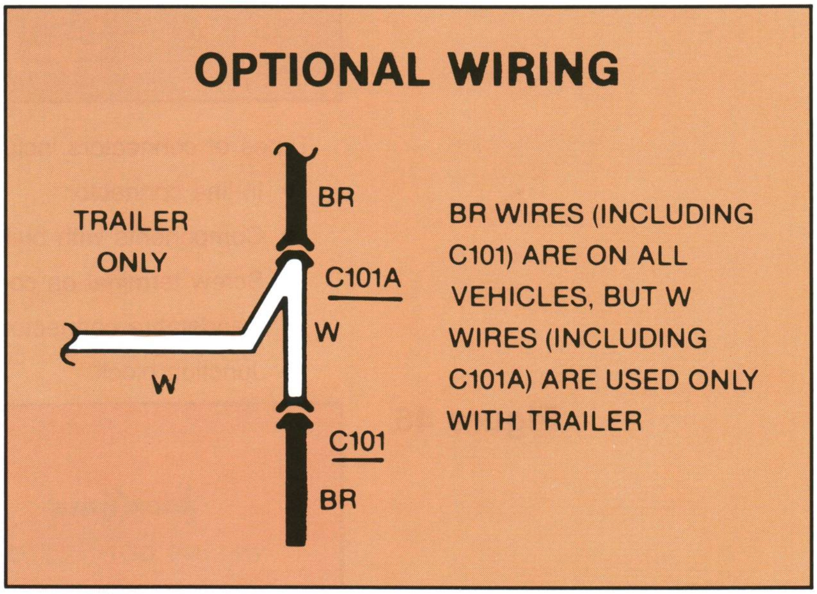
Circuit variations are indicated on the wiring diagram with alternate and optional circuit paths. Alternate circuit paths for another model or for an added component are indicated by a bracket, labeled with the names of the alternate circuits.

Figure 43



When optional equipment requiring additional wiring is placed into an existing circuit, the optional wiring is noted on the wiring diagram.

Figure 44

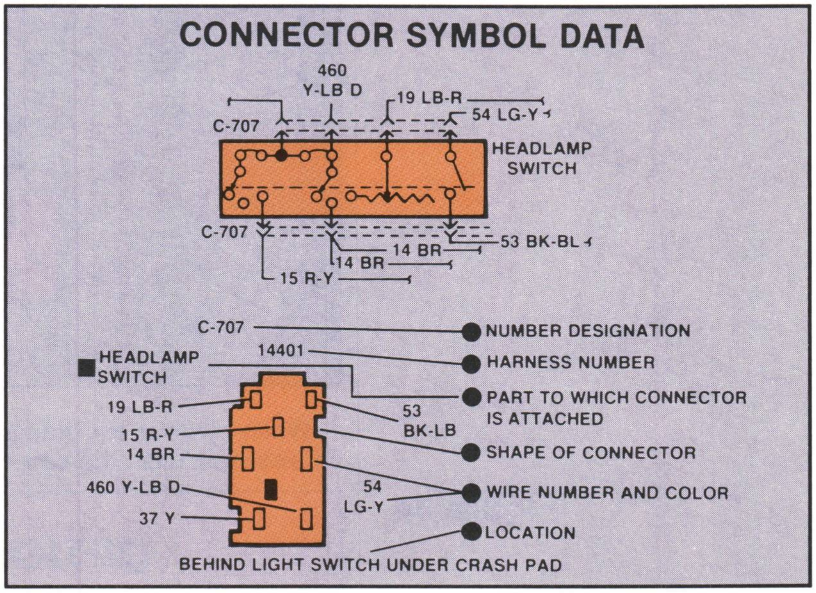

OPTIONAL WIRING
TRAILER ONLY
BR
C101A
W
W
C101
BR
BR WIRES (INCLUDING C101) ARE ON ALL VEHICLES, BUT W WIRES (INCLUDING C101A) ARE USED ONLY WITH TRAILER

Component listings and locations give not only the name of the component but the location of the component on the vehicle. A reference to a page and the figure on the page is provided. To find the location of the component, turn to the page given and it will be contained in the figure. This proves to be valuable when trying to find a component on a vehicle. A generous number of figures are provided which show the actual location of the component. In the figure, the component is highlighted and identified for further aid in locating it.

Troubleshooting hints included define the condition, possible cause, and action to be taken. These are not as detailed as those contained in the Shop Manuals, but do point the Technician in a general direction. They are not intended as a step-by-step procedure as is given in the Shop Manual. The ignition section is an exception to this. It includes a step by step procedure of basic quick steps to locate some of the more common ignition problems.

Connectors are designated on the wiring diagrams with a letter C followed by a number. If the connector has more than one terminal, each wire going to the connector will be joined by a dashed line and have a common connector number. Multi-terminal connectors are shown at the bottom of the wiring diagram and indicate the wire/terminal connections.

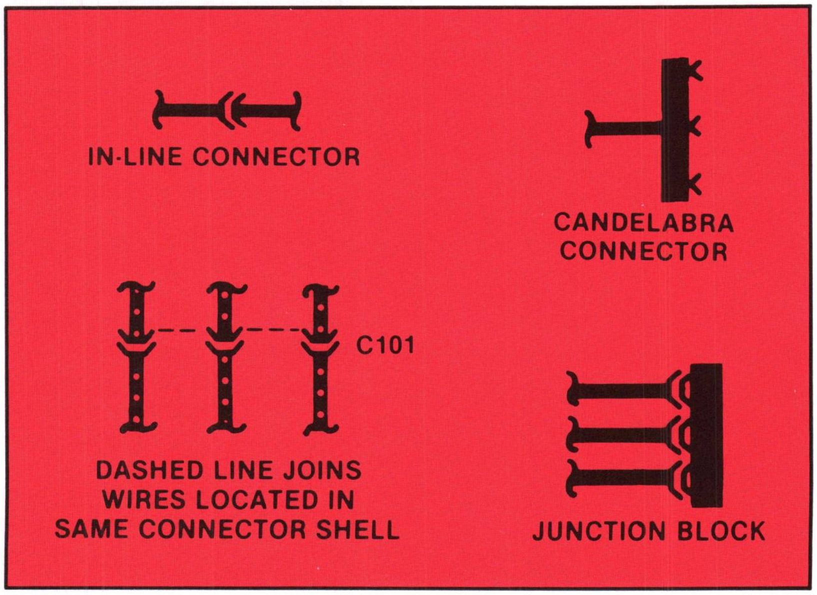
Figure 45



Types of connectors include:

- In-line connector
- Components with built in connectors
- Screw terminal on component
- Candelabra connector
- Junction block

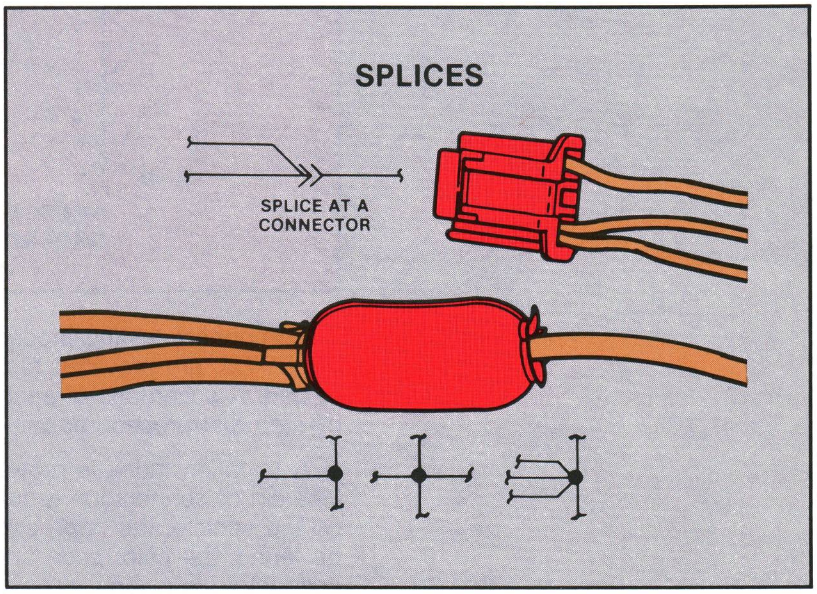
Figure 46



Connector end views of switches and other components are shown in the component testing section to help with bench testing. The views show the harness wire colors that connect to the terminals.

Splice or crimp wire connections are indicated on the wiring diagrams by a solid black dot where two or more conductors meet or cross each other. Each splice is identified by the letter S followed by a number. If two wires cross but there is no black dot, the wires are not spliced or crimped together.

Figure 47



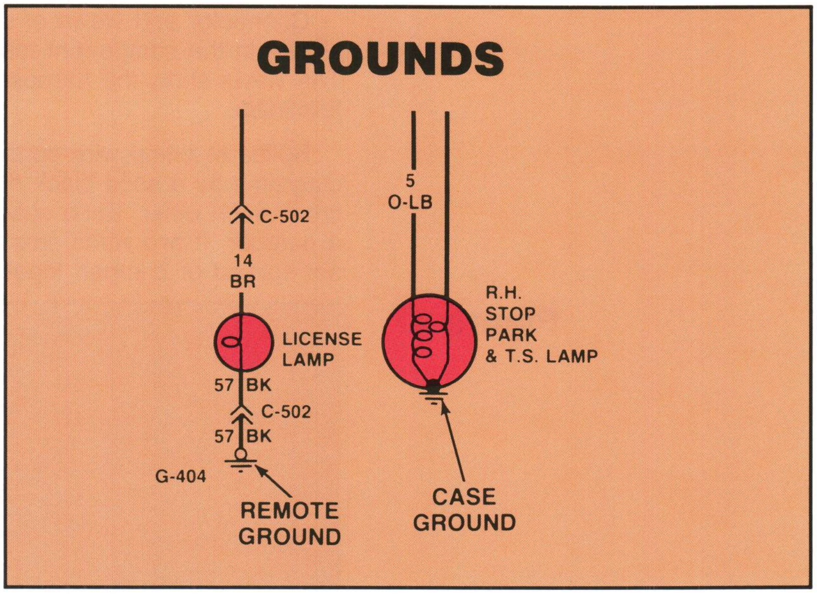
The Grounds pages in the EVTM show detailed views of multiple component ground points. This is useful for checking interconnections among the ground circuits of different diagrams.

Grounds are also shown on the wiring diagrams. There are two types of grounds; case and remote.

Case grounds are used when the component has a metal case and is attached to a well grounded part of the vehicle. On the wiring diagram, this ground is shown at the component itself.

Remote grounds are used where the component itself is not grounded and is shown in the wiring on the wiring diagram. Remote grounds are indicated by the letter G followed by a number. Common grounds exist when several components are connected to the same ground.

Figure 48



Component testing procedures, which are contained in the rear of the EVTM, are provided to determine whether a component is good or bad. A schematic of each component, terminal locations, and step-by-step test procedures are given.

A Location Index is provided in the rear of the manual. It lists the location of connectors, grounds and splices. The location of the item on the vehicle, the page and figure in the EVTM where the item can be found, the color code and the number of terminals on the connectors is given.

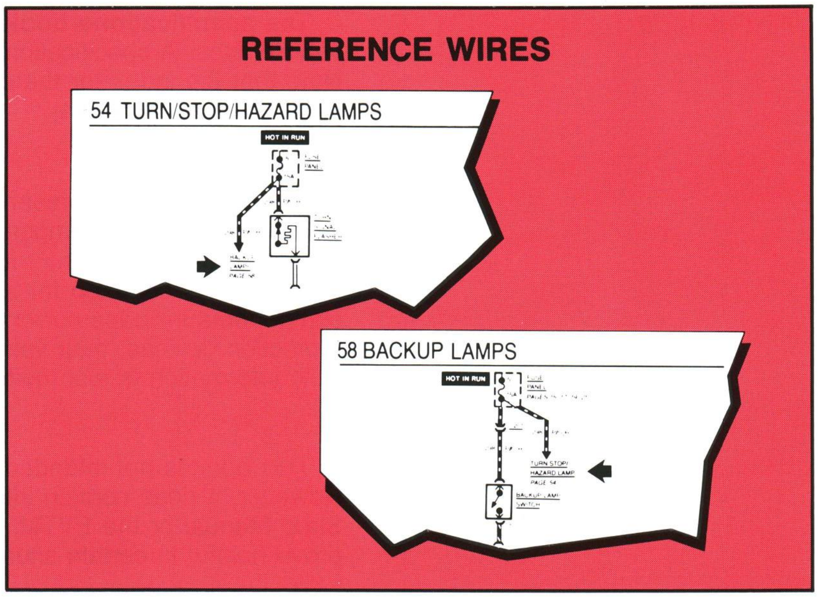
A section on "How to Find the Electrical Problem" discusses the six steps used in troubleshooting. Troubleshooting tools including the voltmeter, ohmmeter, self-powered test light and jumper wire are discussed, as are various tests that can be made with them.

HOW TO USE THE EVTM

Use the contents in the front of the EVTM to find the system and subsystem you desire.

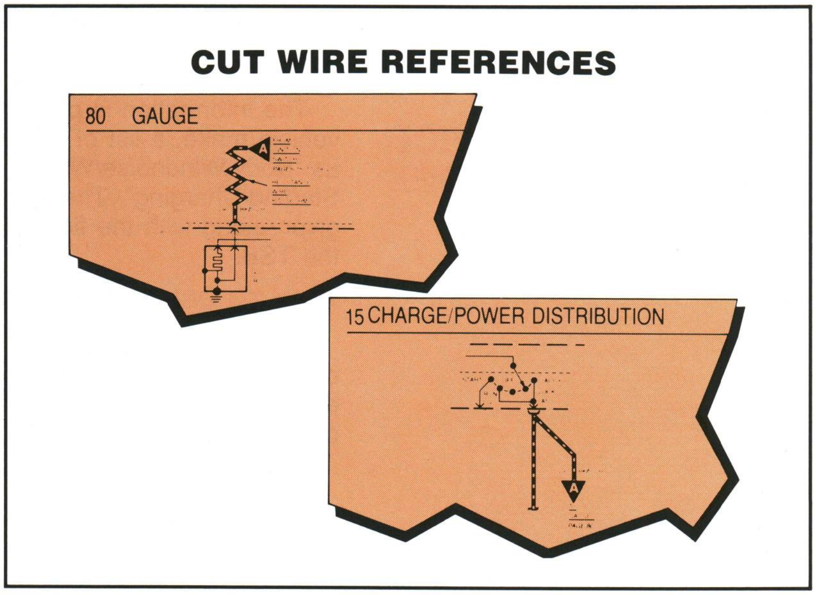
Moving through the circuit may require going to other pages in the manual. **Reference wires** are used to complete wiring shown on another page. They are shown in the circuit as a small solid black arrow at the end of a wire. A note beneath them indicates the circuit and page to which they go.

Figure 49



Cut wire references are used to show current flow from power to ground. They are shown on the diagrams as a large blue arrow with letter inside. A note indicates the item and the page where the wire goes or where it came from.

Figure 50



Connector numbers are shown on the circuit diagram and in the figures which show their location.

Various notes are shown such as when the circuit is "hot".

SPECIFICATIONS BOOK

The **specifications book** contains service specifications for all vehicle lines. A specification book is issued for each model year. Note that the index for the book is in the back of the book instead of in the front as is normal.

INFORMATION CONTAINED IN THE SPECIFICATIONS BOOK

The information is presented in the form of tables and charts. At times drawings and component locations are included. There is generally a separate entry for each vehicle line unless the information is common for all vehicles. Electrical information given for components includes current draw, resistances, and voltages. Circuit protection devices, their values, colors and part numbers are listed. Bulb information is also quite detailed.

HOW TO USE THE SPECIFICATIONS BOOK

This book is not intended for use in troubleshooting and repair. However, it does contain information that may not be available in the Shop Manual or the EVTM. Electrical values or part numbers may prove helpful in certain situations.

To use the book, simply find the item of interest in the index at the rear of the book and turn to the page number indicated.

TECHNICAL SERVICE BULLETIN INDEX

The **TBS Index** provides a quick and easy means of finding needed Technical Service Bulletin information. The TSB Index is issued periodically and contains a listing of **TSB**s for passenger cars, light trucks and medium/heavy trucks.

INFORMATION CONTAINED IN TSB INDEX

The information is presented for each vehicle make. Within each vehicle make, a list of TSBs is given for a series of categories such as "Body/Windnoise/Water Leaks/Trim" or " Electrical/Climate/Starting/Charging". The specific TSB bulletin and article number is given along with the fiche number and the model year affected by the TSB.

HOW TO USE THE TSB INDEX

Using the index, look up the vehicle make in question. Find the category such as "Electrical/Climate/Starting/Charging" and find the detail item of interest which is listed in alphabetical order under each category.

TECHNICAL SERVICE BULLETIN

TSBs are intended to provide the latest information to Service Technicians. They contain "Articles" which deal with items such as: information in manuals requiring clarification, information not available at the time manuals were published, revised service procedures, customer problems etc. TSBs are issued twice a month. The date issued and the bulletin number is contained on the cover of each TSB. The bulletin number is comprised of the year and the number of the bulletin issued for that year. For example: Bulletin No. 87- 22 would be the 22nd bulletin issued in 1987. Each article is numbered. Article 87-22-1 would be the first article in the 22nd TSB issued in 1987. The articles in the TSB are presented in article number sequence.

INFORMATION CONTAINED IN TSB

There are sections in the TSB for cars, light trucks, and medium/ heavy trucks. The articles in each section are arranged by category i.e. Body/Windnoise/Water Leaks/Trim or Electrical/Climate/Starting/ Charging. Each article contains the vehicle affected, the issue and the action to be taken. Other applicable articles are listed as is the warranty status. For warranty items, the operation, time and dealer coding are provided.

HOW TO USE TSB

Since you will be working on a specific vehicle, the easiest and best method is to use the TSB Index since it is arranged by vehicle. First find the vehicle and category of interest to determine if a TSB article has been issued. Once the article number is known, go to the specific TSB and find the article.

NOTE: Be sure the TSB article applies to the vehicle line on which you are working.

WIRING DIAGRAMS

Wiring diagrams present the wiring schematic for the entire vehicle. A separate wiring diagram is presented for each vehicle line. Wiring Diagrams can be purchased individually or in a book which contains wiring diagrams for all vehicle lines. Periodic updates to the wiring diagrams are sent to you as they are released. Because of the size of the wiring diagrams, they are presented as a series of pages. One long wiring diagram has been cut into smaller pieces to make handling easier.

INFORMATION CONTAINED ON WIRING DIAGRAMS

Wiring diagrams contain a schematic of all the circuits in the vehicle. Circuit numbers, wire colors and wire sizes are given. Optional wiring for RPO items is also included. A Standard Circuit Number Chart in the front of the book gives the number of the circuit, its description and the wire color.

Basic electrical and component symbols and their meaning are included in the front of the book.

Connectors in the diagrams present a graphic description of the physical connector to connector interface. Information such as connector outline, circuit number, wire placement and connector location within the vehicle can be determined. The connectors show the physical orientation of the wires to the terminals. All connectors are shown as viewed from the mating surface end. Male connector terminals are shown as a square or circle with an "X" in the middle. Female terminals also use squares and circles but do not have the "X".

An alphabetized Component Index is provided in front of each vehicle wiring diagrams to help locate specific components. The index refers to a zone number. Zone refers to a specific location within the wiring diagram. The index provides coordinates similar to a road map.

HOW TO USE WIRING DIAGRAMS

One of the keys to using circuit diagrams is to be able to move through the diagram. The zone number is the method used. Generally the circuit flows from page to page, but sometimes the circuit jumps to other pages. When this happens, a note is included on the wiring diagram that gives the zone to where the circuit jumps.

OASIS

The On-Line Automotive Service Information System or **OASIS** is a computer based service information system designed to assist service technicians with diagnosis and repair of vehicle problems that are difficult to fix. It helps the technician fix the problem quickly and minimizes the repeat repair by offering symptom related suggestions to each vehicle. Repair actions reported through the OASIS feedback system are continually analyzed by Ford service engineers and repair suggestions are continually added to the system to insure it contains the latest information.

OASIS also contains information on any safety, emission or customer satisfaction field campaigns affecting the vehicle that have not been completed. It contains a directory of any published technical service information that relates to the vehicle.

To use OASIS, the technician enters the vehicle symptoms and identification number of the vehicle into a data terminal with a keyboard and a printer that is connected by telephone to the OASIS computer. OASIS provides the technician with the latest repair information specific to the vehicle and symptom in the question.

A Symptom Book is available that contains symptom codes, setup and operation instructions for the system. A pocket card is available for the technician that contains the symptom codes.

LESSON AGENDA

LESSON 6: CHARGING SYSTEM COMPONENTS

CONTENT

- Charging system operation
- Charging system on-vehicle tests
- Charging component operation
- Charging system component bench tests

INSTRUCTOR OBJECTIVES

The instructor will:

- Discuss the importance of the charging system.
- Explain the operation of the charging system.
- Discuss the operation, testing and maintenance of the charging system components.

TECHNICIAN OBJECTIVES

The technician will:

- Become familiar with charging system operation.
- Become familiar with the operation of the components of the charging system.
- Demonstrate knowledge of the testing of the charging system.
- Demonstrate knowledge of bench testing of the charging system components.

LESSON 6 GLOSSARY

Alternator	A power generating device which outputs power through the charging system to replenish electricity in the battery.
Base Voltage	The voltage measurement across the battery terminals with the ignition switch and all accessories turned off.
Delta Winding	A stator winding that resembles the Greek letter Delta. In the Delta winding, each coil winding end is connected to the end of another coil winding end to form a closed series circuit.
EVR	External Voltage Regulator - A regulator that is not an integral component of the alternator.
IAR	Integral Alternator/Regulator - A solid state voltage regulator located within the alternator.
Load Test	The voltage measurement across the battery terminals with the engine running and all major accessories (heater, A/C and high beams) turned on.
No Load Test	The voltage measurement across the battery terminal with the engine running but no accessories turned on.
Over Voltage Test	This test is made if the No Load test was more than 2.5 volts greater than the Base voltage in either a EVR or IAR alternator system.
Rectification	Changing alternating current, generated by the alternator, into direct current.
Under Voltage Test	This test is made if the No Load test was less than 0.5 volts above the Base voltage in either the EVR or IAR alternator system.
Wye Winding	A stator winding that resembles the letter Y. In the Wye winding a pair of coil windings form a series circuit while the third coil is neutral.

CHARGING SYSTEM

The charging system of the vehicle is rapidly becoming an extremely critical area due to the amount of electronics on todays vehicles. For the various electronic control systems to operate properly, they are totally dependent on the state-of- charge of the battery and the amount of current produced while the vehicle is running.

A run-down battery, or ineffective charging system can produce symptoms that may lead the technician to all sorts of improper diagnosis, unnecessary replacement of parts, and wasted time.

It is vital to be able to quickly diagnose the charging system, and effectively repair or replace components as needed.

OPERATION

When the engine is running, the charging system provides the electrical power needed to operate all of the electrical systems in the vehicle and it recharges the battery if required. When the engine is not running, the storage part of the system, the battery, is used to start the vehicle and to supply power to the electrical systems.

A typical vehicle charging system consists of:

- storage battery
- alternator
- voltage regulator*
- fuse link
- warning indicators
- ignition switch
- necessary cables and wires.

* May or may not be integral with the alternator.

When the ignition switch closes, the storage battery provides the electrical power for starting the vehicle. The electric current needed to power all the electrical systems in the vehicle is provided by the battery during the starting stage. After the engine is started, the **alternator** operates to maintain the proper charge in the battery and supply electrical current to all electrically powered equipment in the vehicle.

If allowed to operate uncontrolled, the alternator output would produce voltages above the safe limits set for the vehicle electrical circuits. A voltage regulator is used to control the alternator output to about 14 volts. The regulator monitors the voltage produced by the alternator and by controlling the strength of the electro-magnet in the alternator, it controls the alternator's output.

To inform the driver of the alternators performance, vehicles have an indicator light or an ammeter located on the dashboard of the vehicle.

TESTS

Charging system tests can be separated into ON-VEHICLE and ON-BENCH. On-vehicle testing will be discussed here and on-bench testing will be covered during the individual component discussions.

Before performing charging system tests on the vehicle, note such conditions as: slow cranking, battery dead, top of battery wet, alternator charge lamp does not come on or never goes out. This information will help in isolating the part of the system causing the problem.

There are numerous tests that can be performed on the charging system. The Service Technician must know WHAT tests can be made, WHEN to perform the test, HOW to perform it and be able to INTERPRET the results.

WHAT tests can be made are discussed in this lesson. These tests should be considered as extra tools in your tool box. Just as the proper tool is selected for the job, the proper test must also be selected. Knowing the operation of the system or component, it's purpose and the circuit details will answer WHEN to perform the test. HOW to perform the test can be found in the Shop Manual. INTERPRETING the results can be found in the shop manual and be deduced from the understanding of the operation of the system, the component and the circuit.

VISUAL INSPECTIONS are quick and easy to make and can provide valuable information or even a solution to the problem. They include checking for a burned fuse link; loose, dirty or corroded battery posts and terminals; corroded or loose wiring connections at the alternator, regulator or engine; and proper alternator belt tension.

NOTE: Do not use test light if vehicle has Message Center!!

BATTERY DRAIN is due to a short in a component or wiring harness or a component remaining on. Use a test light in series with the battery cable to detect current draw.

NOTE: An ammeter must be used for vehicles having a Message Center.

On-vehicle tests are used to check out the alternator and its wiring harness.

Bench tests are performed on the alternator itself.

The following tests are performed to check the alternator and it's wiring harness.

The **Base Voltage** in the battery is determined by measuring the voltage across the battery terminal with the ignition switch, the engine and all accessories turned off.

No Load test is made with engine running and no loads turned on. Voltage across battery is measured with a voltmeter.

The **Load** test is made with engine running and all major loads (heater, A/C and high beams) turned on. Voltage across battery is measured with voltmeter.

The results of the No Load and Load tests are compared with the Base Voltage to determine if an Over or Under Voltage condition exists.

Over Voltage test is made if the No Load test was more than 2.5 volts greater than the Base Voltage in either a EVR or IAR alternator system.

Under Voltage test is made if the No Load test was less than 0.5 volts above the Base Voltage in either a EVR or IAR alternator system.

Regulator S and/or I Circuit test is performed if Under Voltage test results dictate.

Fuse Link Continuity test is made when the battery voltage is OK, but the headlights or any accessory do not operate, since the fuse link may be burned out.

Field Circuit drain determines if the alternator or its circuit has a voltage drain.

BATTERY

The storage battery has three major functions:

1. It provides a source of electrical power for starting the engine and powering components when the engine is not running.
2. It acts as a stabilizer to the voltage in the electrical system while the vehicle is running.
3. It can, for a limited time, furnish current when the electrical demands exceed the output of the alternator.

The battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for, can long and trouble-free service be expected.

There are two types of batteries, Filler and Maintenance-Free. The filler type is an older style battery which has an access cap for each cell. Electrolyte and or water could be added to the battery. The caps can be removed to check the electrolyte level. Maintenance-free types are sealed and do not have removable caps thus electrolyte and or water can not be added. The electrolyte level can be checked by viewing through the plastic case.

OPERATION

During engine starting and Key Off electrical use, some of the battery charge is used up. The battery is recharged by the alternator. If the battery can not accept a charge or hold the charge, battery related problems will occur.

TESTS

CAUTION: Hydrogen and oxygen gases are produced during normal battery operation. This gas mixture can explode if flames, sparks or lighted substances are brought near the battery. When servicing a battery, never smoke, always provide ventilation and shield your eyes.

Batteries contain sulfuric acid which will cause burns on contact with skin, eyes, or clothing. Be careful when handling a battery, removing caps, performing hydrometer tests, or working in any way with battery electrolyte. Shield your eyes in case of an electrolyte splash. In case of acid contact with skin or eyes, flush immediately with water for a minimum of 15 minutes, and get prompt medical attention. Be careful not to allow the electrolyte to touch the vehicle surface. Use fender covers. If the electrolyte is accidentally spilled on the vehicle surface, flush the area with a baking soda and water solution, and repeat with fresh water.

Visual inspection of the battery includes examining the posts for dirt or corrosion which would prevent it from accepting a charge. A dirty or wet battery top can discharge a battery by providing a path for current to flow from one battery terminal to the other. Checks for physical damage such as loose posts and cracked cases should also be made.

Tests can be made on batteries to determine the state of charge and also its capacity or ability to crank an engine. The ultimate result of the tests is to show that the battery is good, needs recharging, or must be replaced.

The following tests can be performed on both filler type and maintenance-free batteries.

State of Charge of the battery is checked with a digital voltmeter to determine its open circuit voltage. If the battery voltage is below 12.4 volts and the battery has passed the capacity test, charge the battery.

Capacity Test of the battery is made using a Rotunda Starting and Charging Tester. Voltage readings at a specified discharge rate in amperes are made. Batteries failing this test are recharged and retested a second time.

In a filler type battery, a hydrometer can be used to check the specific gravity of the electrolyte in each cell. In order to obtain an accurate specific gravity reading, it must be corrected to the standard temperature of 26° C. (78° F.). Refer to the Shop Manual for this correction procedure.

BATTERY CHARGING

CHARGE TIME REQUIRED

The total charge required will vary with battery size and the battery's initial state of charge. In general, to bring a discharged battery to a serviceable state of charge, current-time input should equal the battery amp-hour (AH) capacity. For example: a 45 AH battery will require 15 amps of charge for three hours, or 9 amps of charge for five hours. If a full state of charge is desired, the charge can be completed by a low constant current of 3 to 5 amps for several hours.

BATTERY TEMPERATURE

Cold batteries will not readily accept a charge. Any battery that has been frozen, MUST be allowed to thaw completely before attempting to charge it. Batteries should be allowed to warm up to approximately 5° C. (41° F.) before charging is attempted. This may require four to eight hours at room temperature depending on the initial temperature and battery size.

COMPLETELY DISCHARGED BATTERIES

A battery which has been completely discharged may be slow to accept a charge initially, and in some cases may not accept a charge at the normal charger setting. Batteries in this condition can be started to charge by use of the "dead battery" switch on chargers so equipped.

Completely discharged batteries which have been discharged for a prolonged period of time (over one month) or which have an open circuit voltage of less than 2 Volts may show no indication of accepting a charge even with the use of the dead battery switch. The initial charge rate accepted by batteries in this condition is so low that the ammeter on some chargers will not show any indication of charge for up to 10 minutes.

DETERMINING CHARGE ACCEPTANCE

To determine if a battery is accepting a charge follow the charger manufacturer's instructions for use of the dead battery switch. If dead battery switch is the spring-loaded type, it should be held in the ON position for up to three minutes.

After releasing the dead battery switch (with the charger still on) measure the battery voltage using a voltmeter. If the voltage is 12 volts or higher, the battery is accepting a charge and is capable of being recharged. However, it may require up to two hours of charging with cold batteries below 5° C. (41° F.), before the charge rate is high enough to show on the charger ammeter. All non-damaged batteries can be charged using this procedure. If a battery cannot be charged by this procedure, it should be replaced.

CHARGING METHODS

Once it has been determined that the battery has begun to accept a charge, it can be charged to a serviceable state or a full state of charge by one of two methods.

The first method is to use the automatic setting on chargers so equipped. This setting maintains the charging rate within safe limits by adjusting voltage and current to prevent excessive gassing and spewing of electrolyte.

The second method is to use the manual or constant current setting on the charger. Initially set the charge rate for 30 to 40 amps and maintain this setting for approximately 30 minutes or as long as there is no excessive gassing or electrolyte spewing. If gassing results, the charge rate must be reduced to a level where gassing will stop. This is particularly true for maintenance-free batteries where excessive gassing will result in non-replaceable loss of electrolyte, thus shortening battery life.

FUSE LINK

The fuse link is a short length of insulated wire integral with the engine compartment wiring. It is four (4) wire gauges smaller than the circuit it protects. When heavy current flows or when a short to ground occurs in the wiring harness, the fuse link burns out and protects the alternator and wiring. Note that there are several fuse links in the electrical system.

TESTS

When a fuse link burns out the insulation will be bubbled or expanded. When it is hard to visually determine if the fuse link is burned out, perform a continuity test. Continuity should exist if the fuse link is good.

WARNING INDICATORS

Warning indicators are placed in the vehicles dash to inform the driver of the state of alternator operation. There are two types, an Indicator Light which is illuminated when problems occur and an Ammeter type which shows the actual current being produced by the alternator.

CHARGING SYSTEM COMPONENTS

OPERATION

On vehicles with an Indicator Light, when the ignition switch is in the RUN position, voltage is applied to one side of the indicator light. If the voltage regulator senses that the alternator is not producing sufficient charging voltage while the engine is running, a switch in the regulator closes to complete a ground path for the indicator light and it lights up to alert the driver.

On vehicles with an Ammeter the current flow from the alternator is constantly monitored to show the driver the system output. The automobile ammeter measures current flow in either direction. Current flowing from the battery (alternator NOT charging) shows as a discharge on the ammeter and current flowing to the battery (alternator charging) shows as a charge.

TESTS

A Visual Check of the indicator light can be made with the ignition switch in the OFF and RUN position while the engine is running and not running.

The various conditions are:

IGNITION SWITCH	ENGINE	LIGHT	COMMENTS	
OFF	OFF	OFF	NORMAL	
ON	OFF	ON	NORMAL	
ON	OFF	OFF	PROBLEM	● no power to bulb ● bulb burned out ● poor ground at bulb ● lamp socket resistor missing
ON	ON	OFF	NORMAL	
ON	ON	ON	PROBLEM	● no alternator output ● over voltage condition
OFF	OFF	ON	PROBLEM	● short in rectifier diode

ALTERNATOR

The alternator is belt driven from the engine. It produces power to the charging system in the form of alternating current. The alternating current is rectified to direct current by six diodes. The voltage regulator automatically adjusts the alternator field current to maintain the alternator output voltage within prescribed limits to correctly charge the battery. The alternator is self-current limiting. There are two basic types of alternator systems. The External Voltage Regulator (**EVR**) system has the voltage regulator mounted on the fender apron of some vehicles. The Integral Alternator/Regulator (**IAR**) system has a solid state voltage regulator located within the alternator itself.

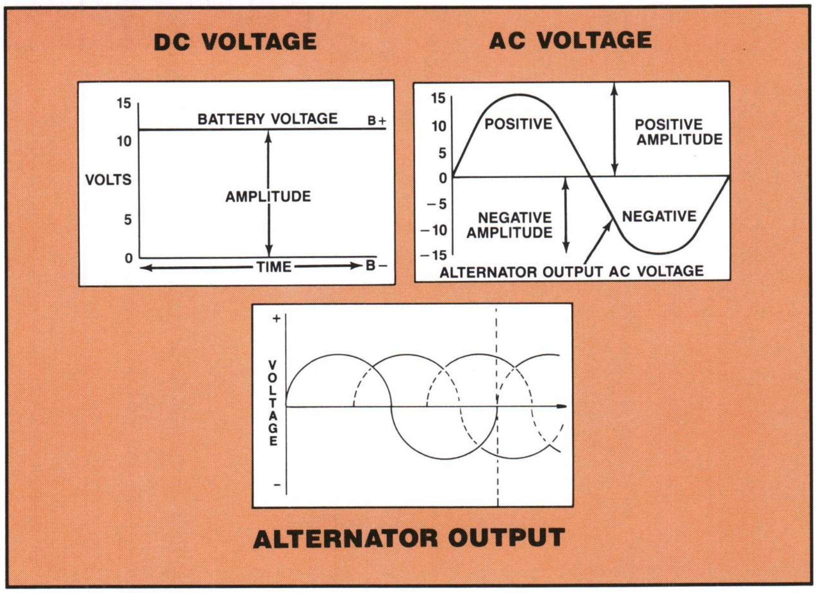
OPERATION

Basically the alternator has a magnetic field which rotates within a conductor and as the magnetic lines of flux pass through the conductor, electricity is generated. The rotating magnet portion is called the ROTOR and the stationary conductor is called the STATOR.

The magnetic field in the alternator is generated by an electromagnet (Rotor). As discussed in earlier lessons, an electromagnet requires electrical current to operate. This electrical current is provided by the voltage regulator through the field circuit. In order to maintain this connection with the spinning rotor, a system of two slip rings and brushes is used. One slip ring is connected to one end of the rotor electromagnet coil and to ground. The other slip ring is connected to the other end of the rotor electromagnetic coil and to the alternator FLD (Field) terminal. The more current provided by the voltage regulator to the alternator FLD terminal, the stronger the electromagnetic becomes and the higher the voltage output from the alternator.

As the rotor spins past the stator windings, current is first induced in one direction, and then in the opposite direction as each pair of rotor magnetic poles passes, thus AC current is generated.

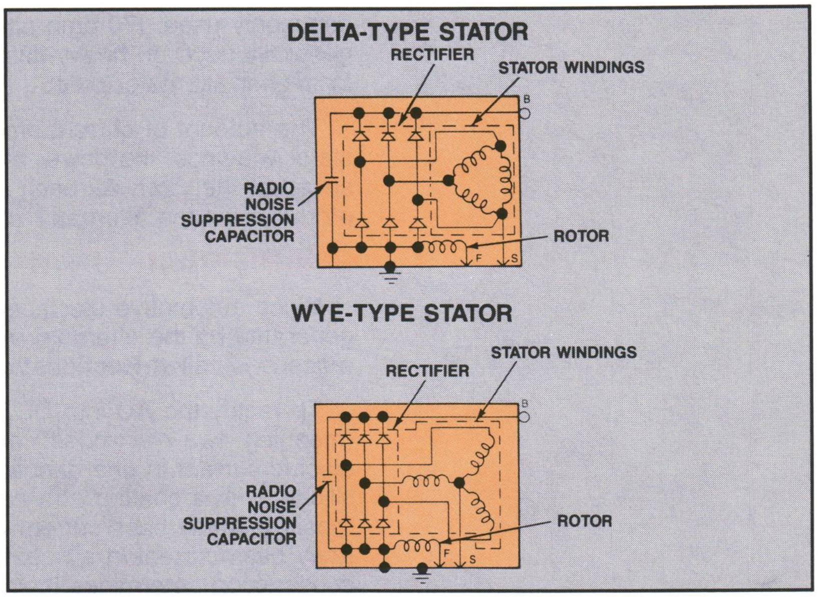
Figure 51



An AC voltage is called a Sine Wave when drawn on a graph. It has a positive amplitude when current is flowing one way and negative amplitude when the current flow reverses.

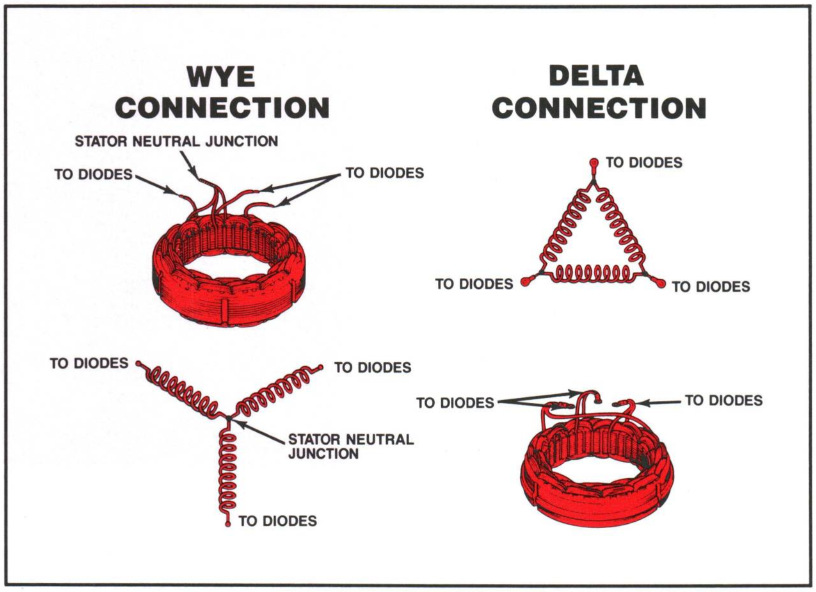
The Stator has three sets of windings, these are shown schematically as three separate coils.

Figure 52



When the magnetic field crosses the first winding, the current starts to build in the conductors of ***Phase 1***. As the field crosses the conductor of ***Phase 2***, current starts to flow in that circuit as well. As the magnetic field continues to cross the ***Phase 3*** windings, current also starts to flow in that circuit. The result is three complete sets of SINE WAVES building and subsiding to zero and then reversing - all in overlapping sequence. The final output of the alternator produces a signal like that shown in Figure 6-4.

Figure 53



There are two types of stator windings used in Ford-built vehicle alternators, the **Delta** and the **Wye**. They are named from their shapes when shown on an electrical schematic. The delta winding resembles the Greek letter Delta (△), and the Wye winding resembles the letter Y.

In the Delta winding each coil winding end is connected to the end of another coil winding end to form a closed series circuit. In the WYE winding each pair of coil windings form a series circuit while the third coil is neutral. The Wye type stator winding is the most commonly used, (70 amp alternators). The Delta type winding is generally used on heavy-duty alternators to allow heavier windings for higher alternator output, (100 amp side terminal alternators).

The amount of current produced is a function of the number of stator windings, the power of the electromagnet and the turning speed of the rotor. As each of these items is increased the power produced by the alternator also increases.

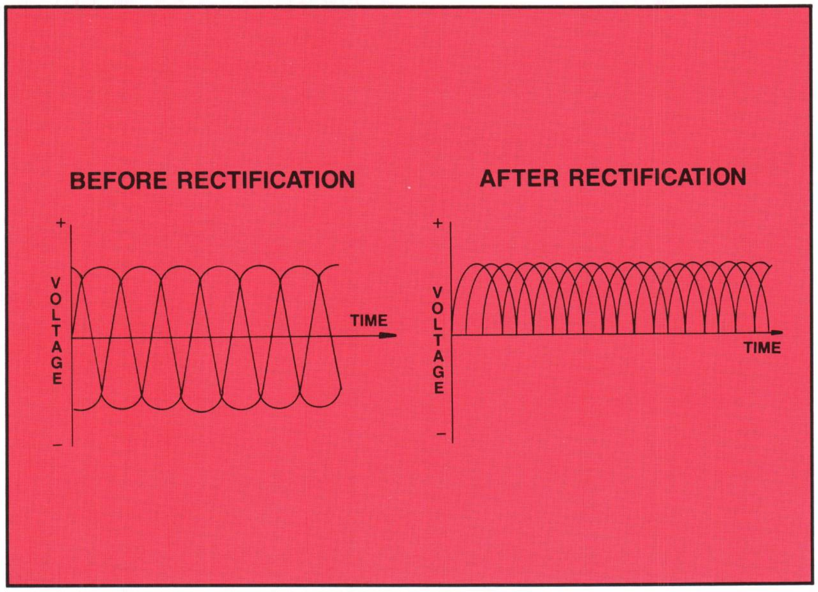
RECTIFICATION

Since automotive electrical systems are DC, the AC current generated by the alternator has to be converted into DC current. This process is called **Rectification** - to rectify or make "right".

To rectify the AC into DC, tiny Semi-Conductors called Diodes (meaning "two electrodes") are used. The diodes will only pass electric current in one direction. They are made of a disc of pure silicon, with a coating of a controlled impurity. Diodes are either "positive" (they pass current in a positive [+] direction) or "negative" (they pass current in a negative − direction). The mechanical construction determines their polarity.

These rectifiers are inserted into the internal circuitry of the alternator so that current will be allowed to flow from the alternator stator windings in a positive direction, but will be stopped if it tries to travel in a reverse direction.

Figure 54



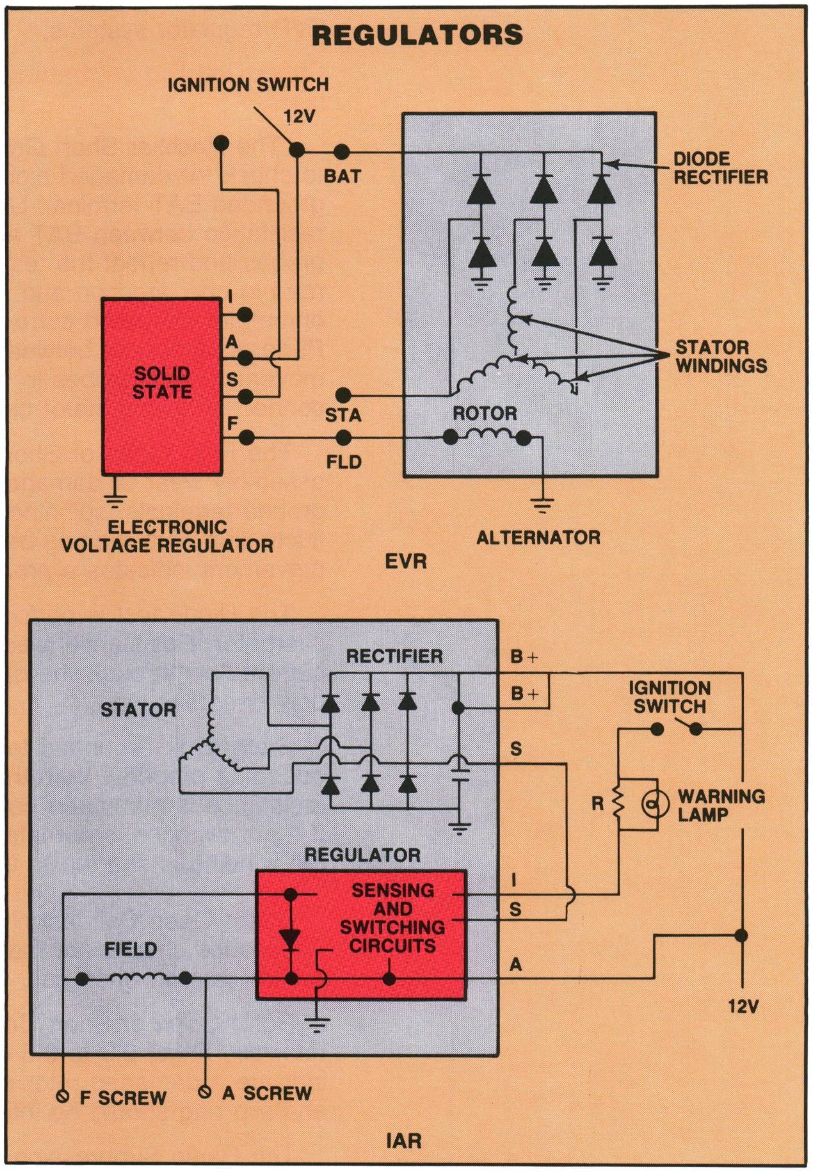
REGULATION

As we stated at the beginning of this discussion on the charging system, the alternator output must be controlled and that's the function of the voltage regulator.

The current voltage regulators used on Ford-built vehicles are 100% solid-state and are not adjustable or repairable. Basically the regulator includes a field switch circuit which controls the FLD (rotor coil) input to the alternator and the electronic control circuit which monitors the stator output and BAT outputs from the alternator. On vehicles with an ALT indicator light, the voltage regulator also includes an indicator switch circuit to control operation of the indicator light.

Voltage regulators can be an integral part of the alternator (IAR system) or a separate component (EVR system).

Figure 54



The electronic control measures a low voltage (battery voltage) at regulator terminal "A" and closes the field switch. This applies battery voltage to the alternator field coil through terminal "F." With current in the field coil, the alternator stator produces a DC voltage output. The input at voltage regulator terminal "S" from the alternator stator is about one half the alternator output to the battery. The electronic control monitors this input and opens and closes the field switch as required to maintain system voltage at about 14 volts. If the input terminal "S" drops below a pre-set value, the indicator switch closes to ground and the indicator light comes on.

The voltage regulator on vehicles with an ammeter operates about the same. However, the "S" terminal input comes directly from the ignition switch. During START, the input is through a resistance wire which causes the regulator to operate the same as the indicator light system with voltage through the indicator light during START.

TESTS

There are a series of bench tests that can be performed on alternators. These tests would be performed if charging system tests isolated the problem to the alternator. Test details are contained in the Shop Manual.

The following bench tests can be PERFORMED on both IAR and EVR regulator systems.

CAUTION: Digital meters can not be used to perform rectifier tests.

The Rectifier Short Grounded and Stator Grounded test is made to check for damaged diodes, a grounded diode plate and a grounded BAT terminal. Using an analog Ohmmeter, measure resistance between BAT and STA terminals. Reverse the Ohmmeter probes and repeat the test. A low resistance (6 ohms) should be read in one direction and an infinite resistance in the other. i.e. ohmmeter can send current through diode in only one direction. Perform same test between terminals STA and GRD. No meter movement with probes in one direction or the other indicates a bad connection in the stator circuit of the alternator.

The Field Open or Short Circuit Test checks the brushes and rotor assembly wear or damage. Using an ohmmeter between field and ground terminals, spinning the alternator shaft should cause a fluctuating ohm reading between 2.4 and 100 ohms. No meter movement indicates a problem.

The Diode test is performed with the rectifier assembly out of the alternator. Resistance readings are taken in both directions to check current flow through the diode. Resistance of 6 ohms should occur in only one direction.

Stator Coil Grounded test is made to determine if the stator coil is operating properly. With the stator removed from the alternator, the resistance is measured between each stator lead and the stator core. If the resistance is not infinite (no meter movement) for each lead, the winding is shorted to the core.

Stator Open Coil test checks for opens in the stator coils. Resistance checks are made between all the leads, infinite resistance will indicate an open coil.

Rotor Open or Short Coil, measure the resistance between the rotor slip rings, 2.3 to 2.5 ohms should be present. Higher readings indicate a damaged rotor coil. Resistance between the rotor shaft and slip ring should be infinite, if not the rotor is shorted to the shaft.

The Radio Suppression Capacitor Open or Short test is performed only on IAR alternators. First the direction of the diodes are determined then the capacitor is charged using the current from the ohmmeter. The leads are momentarily removed and when reconnected, the meter needle should jump indicating the capacitor was capable of carrying a charge.

IGNITION SWITCH

The ignition switch is mounted on the lock cylinder housing and is controlled by the lock cylinder. The lock positions are ACC, LOCK, OFF, RUN, and START.

OPERATION

The ignition switch has blade type terminals that engage with one multiple connector. Depending upon the lock position, the switch will engage various circuits.

TESTS

The ignition switch is tested using an ohmmeter or a self powered test light to test for continuity between the various contacts on the switch.

LESSON 7: DIAGNOSIS

CONTENT

- The Systematic Approach to Diagnosis and Repair
- Problems in circuits

INSTRUCTOR OBJECTIVES

The instructor will:

- Explain the systematic approach to diagnosis.
- Demonstrate types of shorts and high resistance.
- Identify the four basic things that can go wrong in a circuit.
- Direct hands-on practice exercises in following a systematic approach to troubleshooting.

TECHNICIAN OBJECTIVES

The technician will:

- Become knowledgeable in the systematic approach to diagnosis and repair.
- Demonstrate the ability to perform tests that identify various circuit problems.
- Demonstrate proficiency in using test equipment.

LESSON 7 GLOSSARY

Broken Wires	A physical separation in conductive wire.
Extremely High Resistance	Resistance so high that current cannot flow.
Loose Connections	A connector which loses physical contact with its mate disrupting current flow.
Open Internally (Burn Out)	A physical separation causing a lack of continuity in a load.
Shorts Internal to Loads	The physical contact of conductors internal to a load which can cause burn out or strange operational characteristics.
Wire to Ground Short	The physical contact of a current carrying wire and a ground which can cause the circuit to overload.
Wire to Wire Shorts	The physical contact of two conductive wires which can cause strange operational characteristics in the circuit due to current flow through alternate paths.

THE SYSTEMATIC APPROACH TO DIAGNOSIS AND REPAIR

Unless the cause of an electrical problem is immediately apparent, it is always advisable to start at the beginning, and follow tried and proven techniques. The sure-fire approach to electrical diagnosis and repair, is to adhere closely to the following six basic steps:

1. Verify the complaint.
2. Define the type of problem.
3. Isolate the problem.
4. Validate the cause of the problem.
5. Repair the cause of the problem.
6. Test the repair.

Sometimes a technician who is not used to performing electrical diagnosis is reluctant to tackle an electrical repair job. He has some misgivings because he feels he doesn't understand electricity. But what he really doesn't understand is that electrical diagnosis is easy, provided such diagnosis is undertaken in a systematic manner.

VERIFYING THE COMPLAINT

Verifying the complaint is a valuable and necessary first step in conducting an electrical diagnosis. Verifying the complaint tells you two important things: first, it shows you that there is, indeed, a problem; second, it permits you to find out much about the problem at first glance.

Most owners do not give accurate and detailed descriptions of their car's problems. If a driver has a problem in his car's lighting system, for example, he'll usually report something such as, "The lights don't work". This sort of description really doesn't tell you much about the real nature of the problem. So you must verify the problem - check it out - to find out just which light of lights "don't work," which lights do work, and other possibly related symptoms. By thus verifying the problem, you'll actually be well on your way to isolating the problem area. You'll know, for instance, whether the problem is one, or more, or all of the headlights, taillights, parking lights, side marker lights, etc. This gives you a good indication of where to start your diagnosis. If one headlight is out, for instance, it's an entirely different problem than if both headlights are out, or if all the lights are out.

DEFINING THE TYPE OF PROBLEM

The second step in a systematic approach to diagnosis and repair is to define the type of problem. A typical circuit is composed of a battery, conductors, a fuse, a switch, a load and a ground. In any circuit, only four possible things can go wrong and cause a problem.

1. An open circuit
2. A short circuit
3. High resistance
4. Inoperative load

A worn or damaged load usually shows up as an open, short, or high resistance. Often you can tell at a glance just what the source of the problem is.

OPEN CIRCUIT

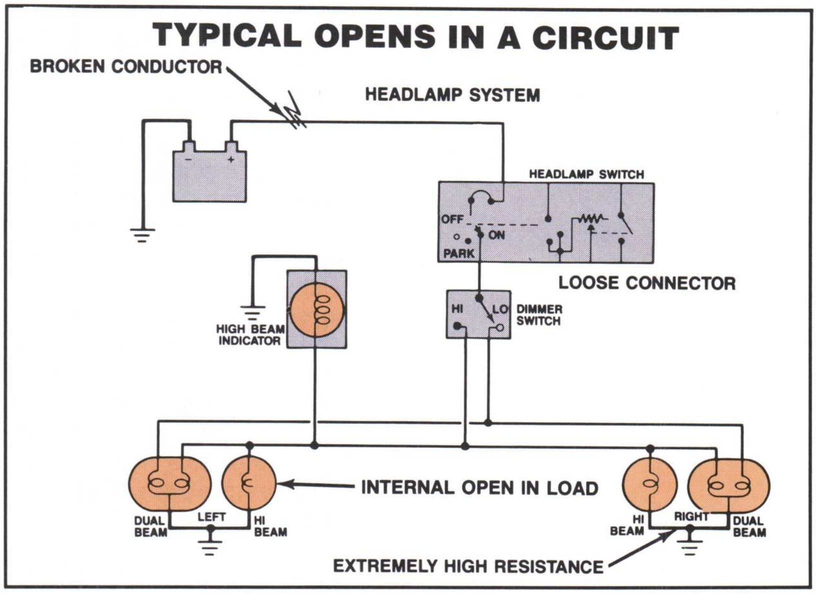
In an open circuit power will not flow through the circuit because there is no complete path for the current from and to the power source. There are two possibilities in open circuits. It could be open constantly or it could be open intermittently.

The most bothersome type is the intermittent open. Intermittence may be caused by a wire that has broken within its insulation, but still is making contact while the car is stopped. Then, when the car is moving and vibrating, the intermittence occurs. In searching for this type of open, you should wiggle the circuit wiring by hand to see if you can cause the open symptom to come and go.

The following are examples of open circuits:

- Broken conductors or loose connectors.
- Blown fuses or circuit breakers open.
- Internally open components such as switches, bulbs, etc.
- Extremely high resistances, which often cause the same symptoms as the other types of open circuits.

Figure 55



TYPICAL OPENS IN A CIRCUIT

Opens due to broken wires are usually caused by accidental damage or vibration. If damaged, the problem is usually visually apparent. Often when the wire is broken by vibration, it is broken within its insulated covering and can only be discovered by testing. There is a good possibility that it will be an intermittent type of open. **Loose connectors** can also be caused by vibration or may be caused during assembly.

Blown fuses and open circuit breakers show up as open circuits. These circuit protection devices open because of overloads. You can usually spot a blown fuse by looking at it. A blown fuse or open circuit breaker is, however, a symptom of a short or overload somewhere in the circuit.

Normal wear will cause certain parts, such as light bulbs, to **open internally** (burn out). The same normal wear will also cause other parts, such as switches and motors, to become open internally after extended use. If such parts wear out after limited service, however, you might suspect some other cause.

Extremely high resistances will often act like an open since the resistance is so high that current will not flow through the resistance. High resistances are usually caused by corrosion in connectors, at terminals or at grounds.

In diagnosing open circuits, inspect for obvious causes such as cut or kinked wires, frayed insulation, and corroded terminals and/or connectors.

In simple series circuits, opens will prevent current flow and all loads in the circuit will not operate. Motors will not run, lights will not light, etc. Before the open, voltage will exist if measured between the circuit and ground. It will not exist after the open.

In simple parallel circuits, opens will prevent current flow and all points that are connected to the power source will be at source voltage.

In complex circuits, opens have different effects on voltage and current. In complex circuits, alternate paths for the current may exist and current will take these paths. Depending on the circuit, some strange operating characteristics may exist that at first glance do not seem to make sense. Looking at the wiring diagram of the circuit may help explain the strange operation.

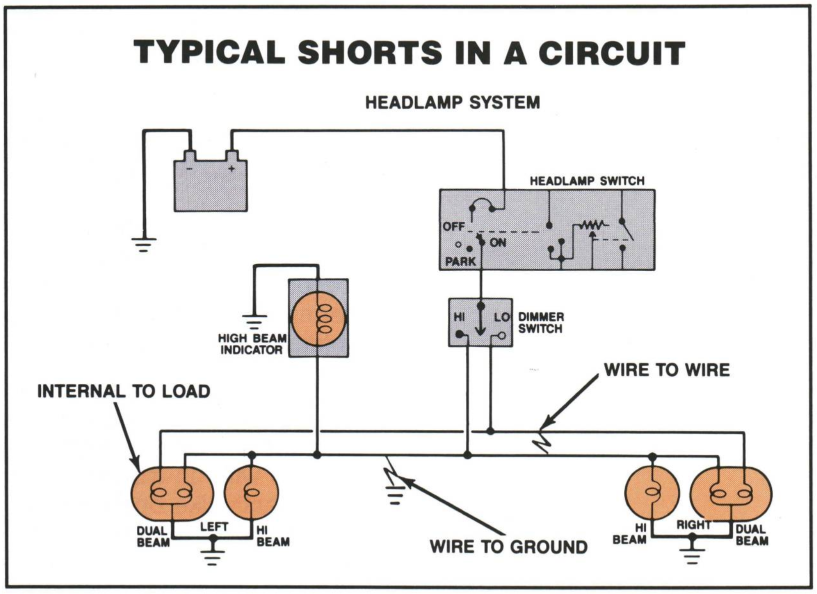
SHORT CIRCUIT

A short circuit occurs when a circuit is completed in a way that was not designed. This happens when a "hot" conductor accidentally makes contact with another conductor or with ground. Short circuits are most noticeable when they create an accidental current path which routes the current away from the load or the control device. Short circuits can also be continuous or intermittent, though intermittents in shorted circuits are not as common as they are in open circuits.

There can be three types of shorts:

- Wire to wire
- Wire to ground
- Internal to loads

Figure 56



Wire to wire shorts can cause some strange operational characteristics in the circuit due to current flowing through alternate paths.

A **Wire to ground** short, depending on where it occurs in the circuit, could cause the circuit to be overloaded (zero resistance will cause an extremely high current flow), and a fuse will blow, a circuit breaker will trip or the conductor could over heat and burn.(Fuses and circuit breakers are designed into the system to prevent this.) If it occurs in the area of a ground, it could in essence replace the ground and no apparent problem will occur. If they occur before components, the circuit in front of the component may work while the operation of the component after the short may be slow, dim etc. due to low current levels.

Shorts internal to loads may occur due to extended overloads, normal wear, or abnormal wear caused by misadjustments, misalignments, etc. When internal shorts occur the component normally quits functioning. Bench tests may be required to determine the cause and extent of the damage to the component.

Like open circuits, short circuits are usually caused by accidental damage or wear due to conductors being pinched against sheet metal by clamps or components, fasteners driven through wires, wires routed over sharp metal edges which cut or chafe through insulation, misplaced metal parts which contact un-insulated portions of wires, etc.

When inspecting for suspected short circuits, look for obvious fraying or bare wires. Like intermittent open circuits, intermittent short circuits are the most difficult type to isolate. Use the same technique - wiggling the wires - to see if you can cause the symptoms to come and go.

Also, be sure to relate the symptoms of the short circuit to its probable location in the circuit.

- A short between the power source and the load will blow a fuse. (If the circuit is un-fused the conductor will overheat, the insulation will melt, and the wire will probably burn in two.)
- If there is a switch between the load and ground and the short is between the load and the switch, the load will be on constantly.
- If the short is between all components and ground, it will have no effect. (In all probability, no problem will be reported.)

HIGH RESISTANCE

A high resistance, in terms of a problem, is any resistance in the circuit that is higher than it is designed to be. High resistances often occur due to corrosion, looseness, or inadequate contact area at terminals, connectors, and grounds. High resistances can also occur internally in components.

A high resistance creates a load and the extra load in the circuit, causes the other loads in that circuit to operate at reduced power. Therefore, where a high resistance exists, lights will glow dimmer, motors will run slower, etc. In extreme cases, high resistances may act exactly like open circuits. If a ground terminal becomes excessively corroded, for instance, its resistance (which is designed to be zero) may become so high that none of the loads in the circuit will operate at all.

High resistance at connectors, terminals, and grounds is usually caused by water, road salt, etc., or by the insulating properties of oil, grease, or dirt that gets into the connection. Loads that develop high resistances may do so because of damage, wear, overloads, or vibration. This internal resistance, like all internal damage, is difficult to spot. Corrosion, oil, etc., in connectors, terminals, and grounds are sometimes visible, but often hard to see with the naked eye. This type of high resistance must be checked with test equipment.

WORN OR DAMAGED LOAD

If the load is worn out or damaged, you may be able to tell just by looking at it. In a light bulb, you can sometimes see a burned out filament or some discoloration. In a motor, sometimes you can see evidence of burning. Often, however, the load shows no evidence of failure. When this happens, you must rely on your observation of the entire system, logic, and particularly, testing to determine that the load has failed. If through observation, you suspect that a part has failed, proceed as follows to make sure:

1. Check that there is power to the component.

2. Check that the component is properly grounded.
3. Test systematically to isolate the problem.

ISOLATING THE PROBLEM

After you have verified and defined the type of problem the third step is isolating the problem. Isolating the problem involves, separating the circuit into simpler circuits. You can separate complex circuits into simpler circuits by two methods - physically by pulling apart connectors, etc., or mentally (and this is where your use of logic is important) by reference to wiring diagrams. Reference to the wiring diagrams allows two significant time savings:

1. The wiring diagrams allow you to separate complex circuits into simpler circuits without physically touching the vehicle.
2. The wiring diagrams allow you to perform some diagnosis mentally, without using test equipment. Testing may be time consuming, especially if done in areas difficult to access.

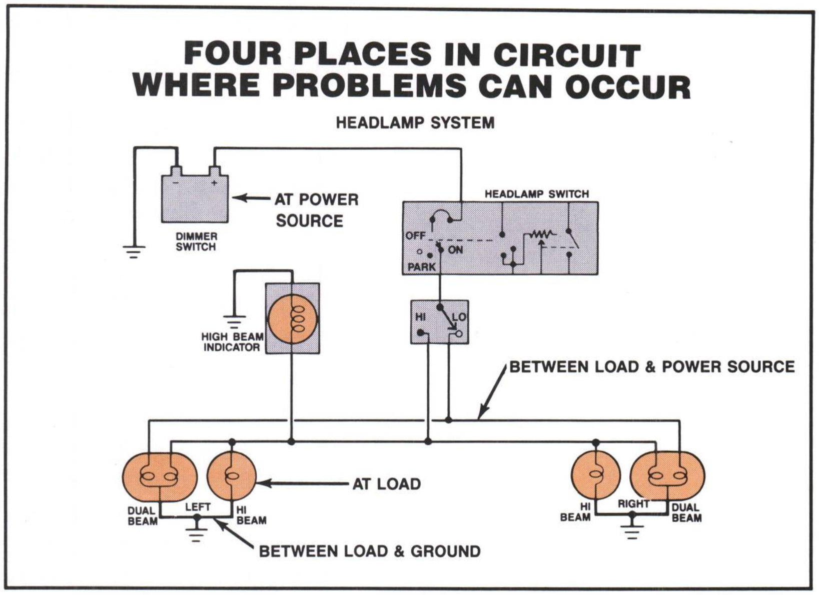
Remember, if one headlight is out, it's an entirely different problem than if both headlights are out, or if all the lights are out. The wiring diagrams and logic, of course, will tell you that if only one headlight is out, the problem is most likely a burnt-out headlight, or at least that it can be found no further away than the wiring splice or connection that provides power to both headlights, or the headlight ground. Often by merely looking at the wiring diagram for a particular system, you can eliminate much of the complex circuit involved in the problem, and concentrate further diagnosis only on the branches that could possibly be the source of the problem.

We have previously seen that there are only four things that can go wrong with a circuit (open circuit, short circuit, high resistance, inoperative load). And we've also seen how to identify the type of problem. Now we need to look at where these types of problems can occur.

They can occur in four places in the circuit:

1. at the load
2. somewhere between the load and the power source,
3. somewhere between the load and ground, or
4. at the power source

Figure 57



FOUR PLACES IN CIRCUIT WHERE PROBLEMS CAN OCCUR

HEADLAMP SYSTEM

If you can match your identification of the problem type with your isolation of the problem area you'll be well on your way to fixing the problem.

PROBLEMS AT THE LOAD

An inoperative load is generally the easiest type of problem to isolate. The load could be faulty, there could be a problem between the load and ground , or there could be little or no current flowing to the load.

PROBLEMS BETWEEN THE LOAD AND GROUND

Poor grounds cause most of the problems in automotive electrical systems. You should always check to determine if the ground is good. If it is good, the problem may be somewhere between the load and the power source.

PROBLEMS BETWEEN THE LOAD AND POWER SOURCE

Generally, if only one component in a system is inoperative, start diagnosis at the component. Again, this advice must be tempered by logic. For example, if a power window motor does not operate, do not begin diagnosis of the problem by taking apart the door to get at the motor. To save time, start by checking the power window switch and other more accessible points between the switch and power source. Don't perform the time-consuming tasks until previous testing has isolated the problem to the motor itself.

When several components in a circuit are inoperative begin your diagnosis at the common source of power.

PROBLEMS AT THE POWER SOURCE

Problems at the power source, like problems at the load, are usually easy to diagnose because everything supplied by the power source will be inoperative. If nothing in the system operates, you know you have a dead battery, damaged battery cables, perhaps a bad ground cable connection, or perhaps a bad connection at the starter terminal.

Although the battery is the ultimate power source, you can consider such things as the ignition switch, fuses, other switches, and splices as secondary power sources.

The advantage in using the wiring diagrams to mentally separate the circuits into simpler circuits, is that you can do it quickly, without touching the vehicle or test equipment, and save time and energy.

TEST SYSTEMATICALLY

Sometimes problems cannot be isolated or, rather, can be isolated only so far by using logic and the wiring diagrams. In these cases, the various types of test equipment at your disposal become invaluable. In order to use the test equipment effectively, you often will have to separate the circuits, physically, into simpler circuits.

SEPARATION INTO SIMPLE CIRCUITS

For testing, circuits can be separated into simpler circuits by either of two methods: separation at connectors and switches, or by cutting and re-splicing when finished.

SEPARATION AT CONNECTORS AND SWITCHES

To simplify a circuit by separating at connectors, pull apart the connector to gain access to the connector terminals for testing purposes. Simpler circuits can also be achieved by opening switches in the circuits.

CUTTING AND SPLICING

In some areas the circuit can be made more simple only by cutting wires. This method is used as a last resort when the circuit must be made simpler than can be done by opening switches, connectors, etc., or in areas where there are no convenient means of opening the circuit. Once you cut the wire, strip the insulation from the wire ends to attach the test equipment. After testing the circuit, clip a butt connector onto the exposed wire ends and securely crimp it. Whichever method you use, the whole purpose is to simplify the circuit to make the most effective use of your test equipment.

VALIDATING THE CAUSE OF THE PROBLEM

The fourth step in the systematic approach to diagnosis is to validate the cause of the problem. After you have isolated a problem using the wiring diagrams and/or test equipment, test to confirm that the original complaint has been eliminated in all modes of operation. This is actuallly the first step in repairing the problem.

REPAIRING THE CAUSE OF THE PROBLEM

Step number five in the systematic approach is to make the repair. It is assumed that the technician, having validated the cause of the problem can perform repairs such as replacing electrical parts. Repairing wiring requires some special techniques which are explained in the lesson on repair.

TESTING THE REPAIR

The sixth and final step in the systematic approach to diagnosis and repair, is to check that the repair does indeed, correct the problem. The final check should be thorough to avoid the possibility of a come-back. When making the final check of the repaired system, be sure to check not only the area of repair, but also all other possibly related systems. Often, particularly in the case of intermittent problems, a road test may be necessary to assure that the problem does not recur under dynamic conditions.

SUMMARY OF THE SYSTEMATIC APPROACH

The importance of using logical and systematic approach cannot be over emphasized. Compared to "seat of the pants" diagnosis or the "replace parts until it works again" methods used by some technicians, this systematic approach will save you time and effort.

Here is a good example of a haphazard approach that has been used times, often by technicians who consider themselves pretty sharp. When one turn signal lamp goes out, for instance, almost everyone's first instinct is to change the bulb. That's not an approved method of diagnosis and repair, but it's not a bad idea; it's a fast method for light bulbs. But when replacing the bulb doesn't fix the problem, often the next instinct is to replace the flasher, and then to think about the switch. Actually, most of the time, when the lamp isn't burned out, the fault is a poor ground at or near the lamp. You can see how the parts replacement method can lead to wasted time and expense.

APPROACH TO BASIC SYSTEM TROUBLESHOOTING

SUMMARY

For any electrical problem there are four places where the cause might originate:

1. An inoperative LOAD.
2. At the POWER SOURCE.
3. Between the LOAD and GROUND.
4. Between the POWER SOURCE and the LOAD.

INOPERATIVE LOAD

If a single inoperative load is encountered, the cause will usually be in the load only or in close proximity to it.

AT THE POWER SOURCE

If a power source is at fault, usually everything in the circuit supplied by that power source will be inoperative. Fuses, switches, splices, etc. can be considered as secondary power sources for diagnostic purposes.

BETWEEN LOAD AND GROUND

This fault is the result of a high resistance, normally caused by corroded or loose connections. An open connector will also cause a similar problem.

BETWEEN THE POWER SOURCE AND LOAD

This fault is usually more difficult to correct because of the location of the fault within the circuit. It is best to divide the circuit at all secondary power sources and check for shorts and opens by traditional troubleshooting techniques to zero in on the fault.

GENERAL GUIDELINES

- When only one component in a system does not operate, begin diagnosis at that component.
- When several components in a system do not operate, start diagnosis at the common source of power (switch, fuse, splice, etc.), or at a common ground if one exists.
- Where there is a choice, check all the applicable access points for voltage and/or continuity, before non-accessible points. Don't make unnecessary work for yourself by disassembling a component before definitely knowing that it is the component that has failed. This can be determined by previous testing.
- Become familiar with and use the diagnostic aids available. Know how to read and use Wiring Diagrams, EVTMs and Shop Manuals.

LESSON AGENDA

LESSON 8: ELECTRICAL/ELECTRONIC REPAIRS

CONTENT

- Wiring repairs
- Connector repairs

INSTRUCTOR OBJECTIVES

The instructor will:

- Define the methods of wiring repair.
- Define the methods of connector repair.
- Direct hands-on practice in wiring and connector repair procedures.

TECHNICIAN OBJECTIVES

The technician will:

- Demonstrate ability to make wiring repairs
- Demonstrate ability to make connector repairs

LESSON 8 GLOSSARY

Amp-type Connectors	Connectors which have a bridge on the pin half and latching legs on the socket half.
Ford Blade Connectors .	Connectors that have T-shaped cavities in the mating end of the socket half of the shell.
Internal Locking Finger Connectors	Connectors that have fingers which are clearly visible in the contact cavities in the shells mating ends.
Locking Wedge Connectors	Connectors that have red or brown wedge release tabs which are visible through windows in the connector shell.
Printed Circuit Connectors	Connectors that have terminals which are rounded at the ends and the ends are visible at the mating end of the shell.
Tang-Type Connectors ..	Connectors that have uniquely shaped latching tongues with plastic springs.

WIRING REPAIRS

Problems can occur in the wiring of the circuit in either the wire itself or in a connector. The technician must be able to repair both wire damage and connectors.

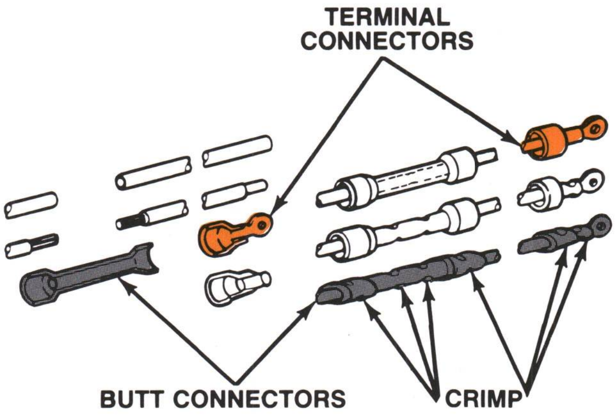
Wires can be repaired two ways; attaching the ends of the existing wire together or splicing in a new piece of wire.

In making wiring repairs it is important that you always replace wires with wires that are at least as heavy as the circuit being repaired. Wire gauge numbers are inverse to their weight (a 14-gauge wire is heavier than an 18-gauge wire).

Wires are color-coded to aid in identification. When possible, use wires with the same color code as the wires being replaced.

Figure 58

TERMINAL AND BUTT CONNECTORS



Wires can be attached in two ways. One method is to solder the ends together and the other is to use a butt connector. The butt connector is quicker and easier to use since it is simply crimped to the wires after the insulation is stripped back. Terminal connectors are crimped on the end of a wire.

SOLDERING INFORMATION AND TECHNIQUES

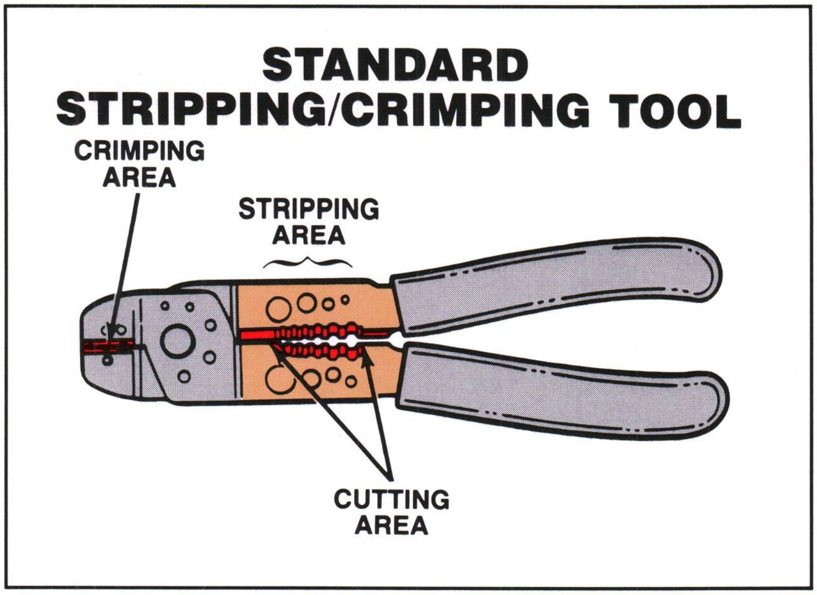
Usually, a light duty soldering iron is all that is required to effect a repair on an automotive harness. However, good soldering techniques are essential for reliable connections. Here are five steps to help you solder successfully:

1. Always use rosin core solder when soldering electrical/electronic components.
2. Solder will NOT adhere to paint, grease, oil, wax, or melted insulation. Make sure the area you intend to solder is clean and free from oil and/or dirt. There are solvents and commercial degreasers available to do the job.
3. The soldering iron tip should be kept clean and should appear shiny when soldering. Wipe off debris with a damp sponge or cloth.
4. Apply heat to the connection for a few seconds with the hot tip of the soldering iron. Leave the iron in place and add solder to the connection. Allow the solder to melt on the conductor it is applied to, and NOT on the soldering gun tip. Solder melted by the gun will not necessarily flow into the conductor.
5. Allow the solder to flow through and around the connection before removing the iron. When removing the iron, be careful not to move the connection before the solder has cooled.

SAFETY PRECAUTIONS

- Soldering irons usually operate at over 700° F. and are capable of inflicting severe burns and starting fires.
- Unplug the soldering iron when it's not being used.
- Always replace the iron in its stand.
- Be sure that there is adequate ventilation in your work area.
- Keep your work area as clean and neat as possible.

Figure 59



STRIPPING AND CRIMPING

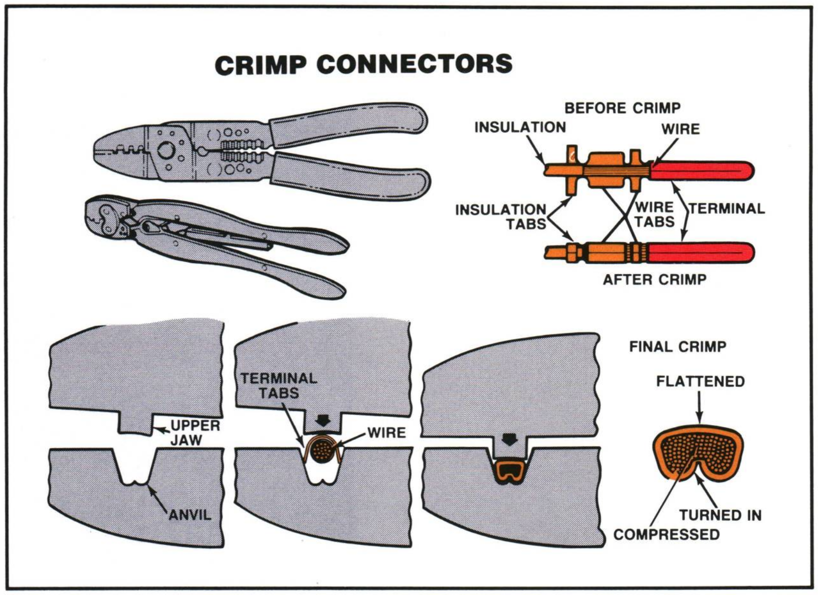
Butt connectors and other styles of wire connectors are attached to the wire using a crimping tool. A standard wire stripping and crimping tool has three working areas; for cutting, for stripping, and for crimping. Note that the tool has different sizes for stripping and crimping. The terminal and butt connectors are color-coded according to the wire gauges they accept:

- Red = 18 to 22 gauge
- Blue = 14 to 16 gauge
- Yellow = 1 to 12 gauge

To strip a wire and/or crimp on a connector:

1. Using the proper size stripping hole to avoid cutting or nicking the wire strands, strip off enough insulation to get full penetration of the wire into the connector.
2. After selecting the proper gauge connector, crimp it on securely in the area of the stripped wire using the proper hole on the tool.
3. Crimp the connector in the area of the wire insulation (two crimps on terminal connectors, four crimps on butt connectors).
4. In areas where the connector will be exposed to weather, use shrink tubing or securely tape the joint to keep out moisture.

Figure 60



To test the crimp, pull on the wires. It should not be possible to pull the wire out of a good crimp. Use an ohmmeter to check resistances across the joined wires or across the terminal and wire. There should be no measurable resistance from one side of the crimp to the other.

SPLICING WIRES

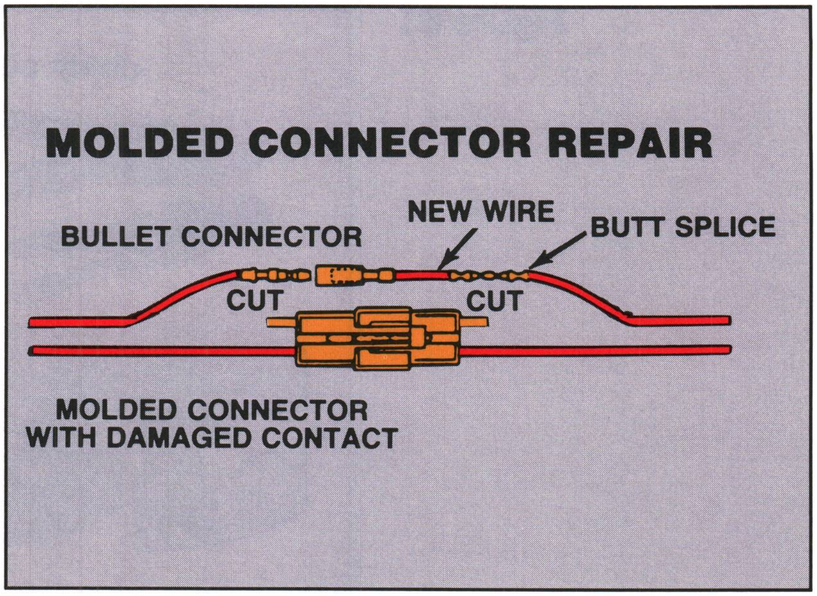
Wires which are open, exposed, or otherwise damaged are repaired by simple splicing. Where possible, if the wiring harness is accessible and the damaged place in the wire can be located, it is best to open the harness to check for all possible damage.

In inaccessible harnesses, the harness may have to be bypassed as follows:

1. Locate both ends of the damaged wire.
2. Cut the wire near both ends of the harness wrapping.
3. Crimp a sufficient length of new wire at both cuts, bypassing the harness.
4. Cover the exposed ends and connectors with heat shrink tubing (or tape).

When replacing fuse links be sure to use released (14526) fuse-link wire - never ordinary wire. Use a fuse link wire that is four gauge sizes smaller than the wire in the circuit. (If the circuit wire is 14 gauge, use 18 gauge fuse link.) When crimping 16-, 18-, or 20-gauge fuse link to a heavy-gauge wire, always double the stripped end of the smaller fuse link to improve contact and retention after it is crimped.

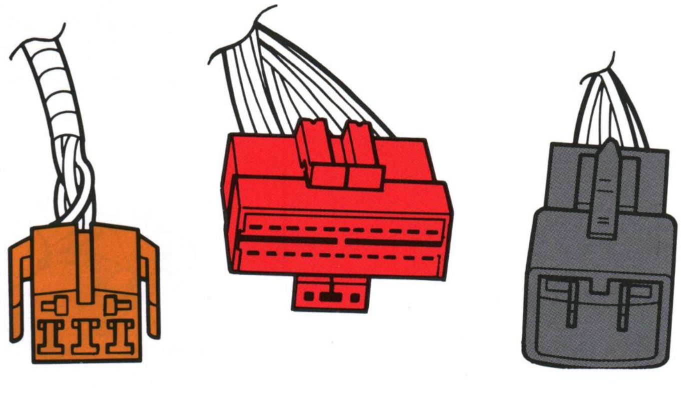
Figure 61



Molded connectors do not have removable contacts. To bypass damaged contacts in molded connectors, use bullet connectors. Use shrink tubing or tape the connection if it is exposed. Always use a Female Bullet connector on the side to the power source.

Figure 62

HARD-SHELL CONNECTORS



REPAIRING HARD-SHELL CONNECTORS

Unlike molded connectors, the terminal contacts in most hard-shell connectors can be replaced. Hard-shell connectors that are weatherproof (like solid-state ignition module connectors) and certain other hard-shell connectors in which the leads are molded into the shell, have non-replaceable terminals. Whenever the connector shell shows evidence of burning, melting, or breaks or cracks, replace the connector shell. Replace individual terminals that are burnt, corroded, distorted or loose.

To replace a connector terminal:

1. Remove the terminal from the connector shell.
2. Cut the wire as close as possible to the terminal.
3. Strip the wire, using the correct tool. (Insulation should project beyond the insulation crimp tabs, but should not touch the wire crimp tabs.) The wire should project into the terminal approximately 1/16-inch beyond the wire crimp tabs.

NOTE: The insulation crimp must be tight to prevent the insulation from sliding back on the wire when the wire is pulled. The insulation must be visibly compressed under the crimp tabs. The ends of the crimp tabs must be turned in for a firm grip on the insulation.

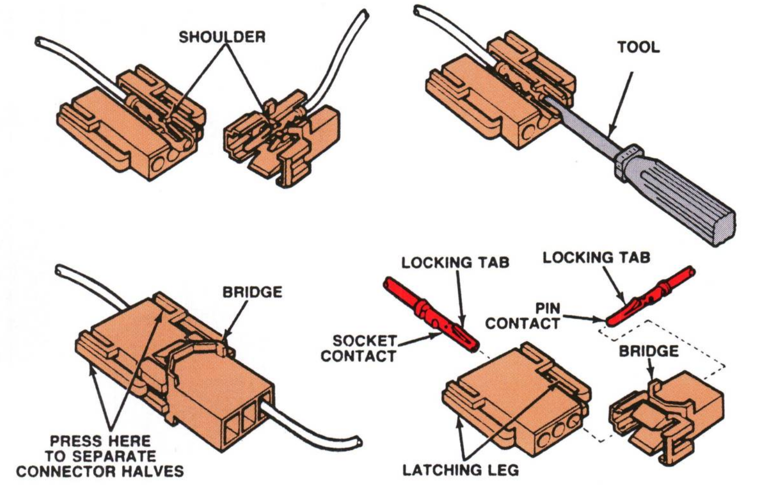
The wire crimp must be made with all wire strands inside the crimp. The terminal must be fully compressed on the wire strands. The ends of the crimp tabs must be turned in to make a firm grip on the wire. To assure proper crimps the crimping tool must have anvil-shaped crimping jaws to turn in the ends of the crimp tabs, as well as different size jaws to accommodate different size wires.

To test the crimp, attempt to pull the wires out of the terminal. Use an ohmmeter across the wire and terminal to check for a good crimp. There should be no measurable resistance between the wire and terminal.

REPAIRING AMP-TYPE CONNECTORS

Figure 63

AMP-TYPE CONNECTOR REPAIR



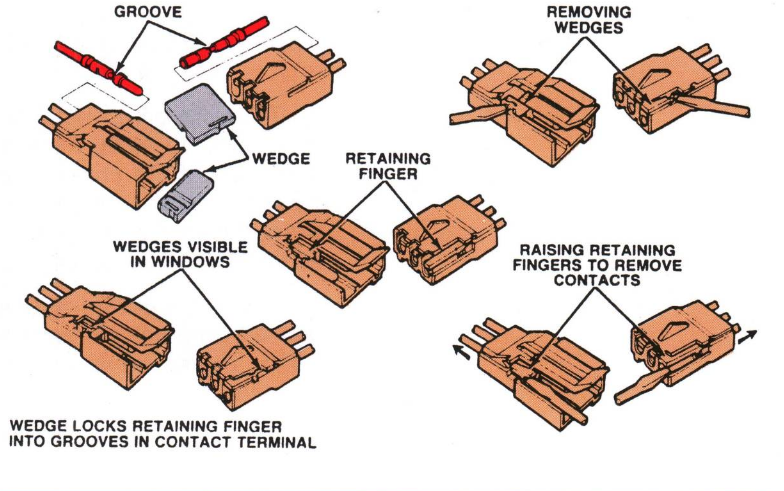
Amp-type connectors can be identified by a "bridge" on the pin half and "latching legs" on the socket half. The pins and sockets are held in the shell by locking tabs. To replace a pin or socket:

1. Squeeze the tabs to separate the connector.
2. Insert special tool C4AZ-17018-B into the mating end of the shell, over the pin or socket to be replaced.
3. Push in on the wire to free the locking tab.
4. Push in and rotate the tool to force the locking tab to retract into the pin or socket.
5. Pull on the wire to pull the pin or socket from the shell.
6. Using standard techniques, crimp on the proper size and type new pin or socket.
7. Push the pin or socket into the shell until the retaining tab snaps out behind the shoulder in the shell.

REPAIRING LOCKING-WEDGE CONNECTORS

Figure 64

LOCKING WEDGE CONNECTOR REPAIR


GROOVE
REMOVING WEDGES
WEDGE
RETAINING FINGER
WEDGES VISIBLE IN WINDOWS
RAISING RETAINING FINGERS TO REMOVE CONTACTS
WEDGE LOCKS RETAINING FINGER INTO GROOVES IN CONTACT TERMINAL

Locking wedge connectors can be identified by red or brown colored wedge release tabs which are visible through windows in the connector shell. The pins and sockets are held in the shell by plastic retaining fingers which are part of the shell and which snap between two shoulders on the pins and sockets.

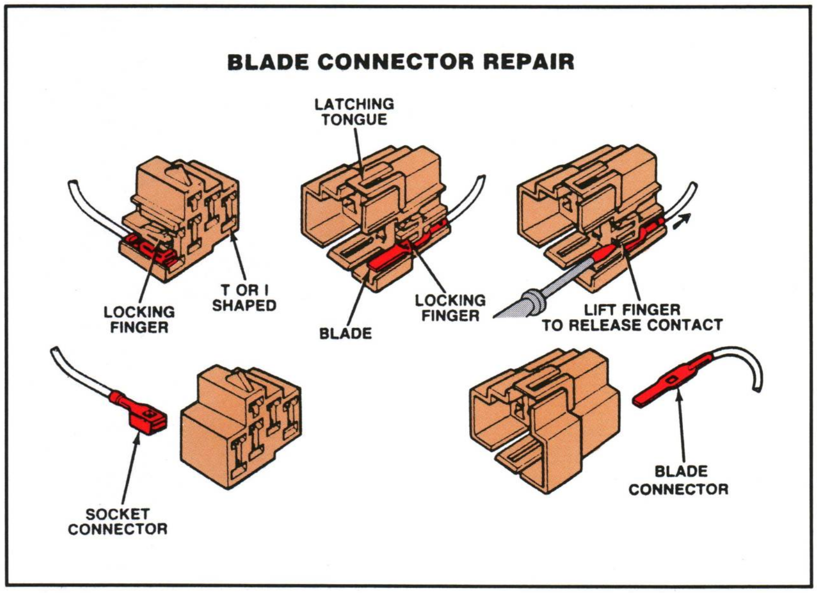
The wedges are held in the shell by a snap-lock tab on one end of each wedge which snaps into the window in the shell when the wedge is fully seated. To replace a terminal in a locking-wedge connector:

1. Lift the latch tongue and pull the connector halves apart.
2. Press the wedge locking tab in and up (toward the mating end of the shell) until the wedge is forced out of the cavity in the shell.
3. Use a 1/8-inch wide screwdriver blade to lift the retaining finger away from the pin or socket.
4. Pull on the wire to withdraw the terminal pin or socket.
5. Replace the pin or socket with the proper size and type new pin or socket, according to standard techniques.
6. Insert the pin or socket into the shell.
7. Push on the wire until the retaining finger snaps into place in the pin or socket.

NOTE: Wedges are not included in replacement shells. When ordering new shells, also order the proper size wedge separately, under basic part number 14A468.

REPAIRING FORD BLADE CONNECTORS

Figure 65



BLADE CONNECTOR REPAIR

Ford blade connectors are identified by the T-shaped (or joined T-shaped, I-shaped) cavities in the mating end of the socket half of the shell, and by the visible blade terminals in the male half of the shell. The blades and sockets are held in the shell by plastic locking fingers, which are part of the shell, and which snap into rectangular cutouts in the blades and sockets.

The sockets are designed to make firm contact against both sides of the blades. To replace a blade or socket:

1. Lift the latch tongue and pull the connector halves apart. The spring-loaded feature of the sockets against the blades make the connectors characteristically difficult to pull apart.
2. Use a 1/8-inch wide screwdriver blade to lift the locking finger away from the blade or socket. The locking nib on the locking finger is deeper than on wedge connectors. The finger must be forced well back to free the blade or socket.
3. Pull on the wire to withdraw the blade or socket.
4. Replace the blade or socket with the proper size and type new blade or socket, according to standard techniques.
5. Insert the blade or socket into the shell.
6. Push on the wire until the blade or socket snaps into place.

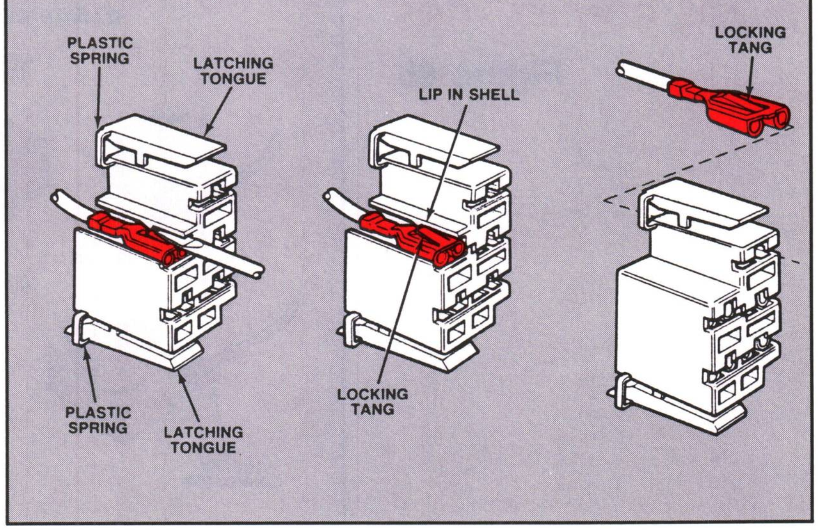
NOTE: When joining the connector halves, make sure the two halves are pushed firmly together. The blades and sockets make very firm contact when engaged; strong pressure is required to join, as well as separate them. After joining the connector halves, always inspect the connector to make sure that the latching tongue is all the way over its mating nib.

Note also that the socket half of the blade connectors is sometimes used to connect to components which have blade-type contacts.

REPAIRING TANG TYPE CONNECTORS

Figure 66

TANG-TYPE CONNECTOR REPAIR



Tang-type connectors are primarily used to connect the harness to the ignition switch. They are identified by the unique shape of their latching tongues which have plastic springs.

Sockets are held in the shell by tangs on the socket which snap out behind lips in the shell. To repair a tang-type connector:

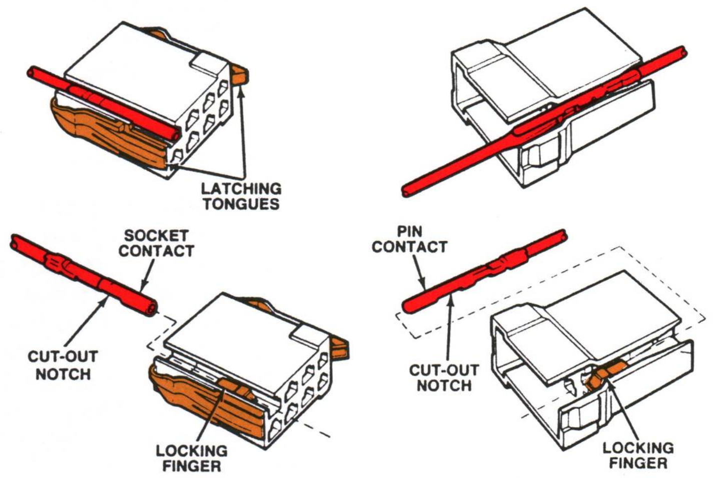
1. Squeeze the locking tongues at the spring end and pull the connector off.
2. Insert a 1/8-inch screwdriver blade (or a heavy paper clip) into the narrow slot beside the socket.

3. Push on the wire (toward the mating end of the connector) and press in on the screwdriver (or paper clip) to force the tang down even with the socket.
4. Pull on the wire to withdraw the socket from the shell.
5. Replace the socket with the proper size and type of new socket, according to standard techniques.
6. Align the tang on the socket with the narrow slot on the shell.
7. Push in on the socket until the tang snaps into place behind the lip in the shell.

REPAIRING INTERNAL-LOCKING-FINGER CONNECTORS

Figure 67

LOCKING FINGER CONNECTOR REPAIR



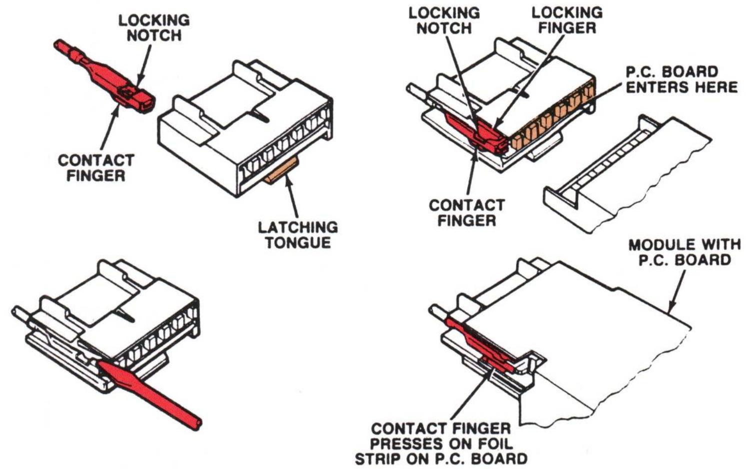
Internal-locking-finger connectors are identified by the fingers which are clearly visible in the contact cavities in the mating ends of the shell. The plastic fingers, molded into the shell, engage cutout notches in the pins and sockets to hold them in the shell. To repair an internal-locking-finger connector:

1. Lift the latching tongues and pull the connector halves apart.
2. Insert a 1/8-inch screwdriver blade into the mating end of the pin or socket cavity.
3. With the screwdriver blade, lift the plastic finger away from the pin or socket.
4. Pull on the wire to withdraw the pin or socket from the shell.
5. Replace the pin or socket with the proper size and type new pin or socket, according to standard techniques.
6. Align the notch in the pin or socket with the plastic finger in the cavity of the shell.
7. Push the pin or socket in until the finger engages in the notch.

REPAIRING PRINTED CIRCUIT CONNECTORS

Figure 68

PRINTED CIRCUIT CONNECTOR REPAIR



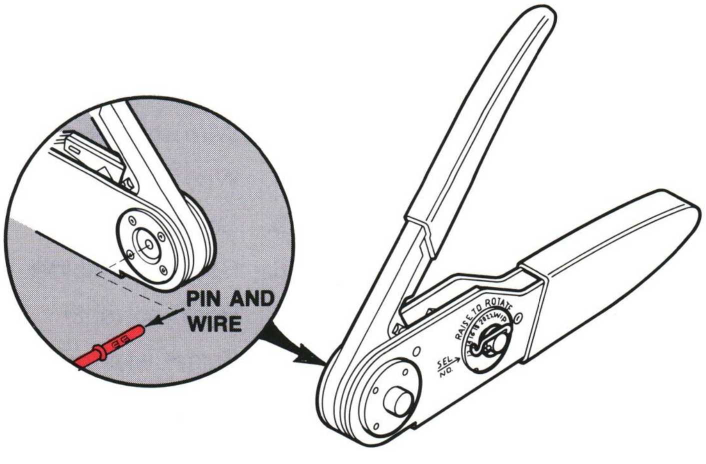
Printed-circuit connectors are identified by the rounded ends of the terminals that are visible at the mating end of the shell. Contact fingers on the terminals protrude through partitions in the shell into the cavity which receives the printed circuit board. The connector contacts have spring-loaded fingers which press against copper strips on the printed circuit board when the board is inserted into the cavity in the shell. The connector contact terminals are held in the shell by plastic locking fingers, which are part of the shell, and which snap into rectangular cutouts in the contact terminals. To repair a printed-circuit connector:

1. Lift the latching tongue and pull on the wires to separate the connector from the component.
2. Using a 1/8-inch screwdriver blade, lift the locking finger away from the contact terminal. (The locking fingers are on the side of the contact opposite the printed circuit board.)
3. Pull on the wire to withdraw the contact terminal from the shell.
4. Replace the terminal with the proper size and type new terminal, according to standard techniques.
5. Align the new terminal so that the contact finger on the the terminal faces the printed circuit board cavity in the shell.
6. Insert the terminal into the channel in the shell.
7. Push the terminal in until the retaining finger snaps into place in the cutout in the terminal.

FORD SPECIAL CRIMPING TOOL

Figure 69

FORD SPECIAL CRIMPING TOOL



A special crimping tool is available from Ford for making crimp-type repairs. The tool is used in conjuction with the wiring harness terminal repair kit. The tool crimps the connector in four places compared to the two place crimp made with a standard crimping tool.

The wiring harness repair kit contains various pins required to repair connectors and wiring. These pins have a gage mark which defines the proper amount of insulation to be stripped from the wire, before making the crimp.

The connector or pin is inserted into the tool, then the wire is inserted into the connector or pin. Squeezing the tool completes the crimp.

The wiring repair kit also contains a special seal that is used with bullet connectors. The seal fits over the repair and provides a water tight seal.

The recommended priority of wiring repair methods is:

1. Ford Special Crimping Tool
2. Soldering
3. Crimping with a standard crimping tool

BASIC ELECTRICAL TOOL LIST

The following list is a basic assortment of tools that will enable you to work on automotive electrical/electronic components and circuitry.

1. Wire cutting pliers
2. Long nosed pliers
3. Wire strippers
4. Wire crimping tool
5. Soldering iron
6. Rosin core solder
7. Rosin solvent
8. Solder wick or solder sucker
9. Solder flux
10. Common screwdriver
11. Philips screwdriver
12. Torx screwdriver
13. Multimeter
14. Jumper leads
15. Shrink tubing
16. Heat gun (for shrink tubing)
17. Spare wire (of various colors and in 12, 14, 16, 18 and 20 gauges)
18. Masking tape.
19. Razor blade and/or knife (for opening harnesses)
20. Nylon tie straps
21. Electrical tape
22. Sharp probe (to penetrate conductors for testing)

SAFETY PRECAUTIONS FOR ELECTRICAL WORK

The following safety preocautions should be followed when performing electrical work.

- Always wear safety glasses while working with soldering equipment.
- Insure that POWER is removed from the circuit under repair.
- Make sure the area you are soldering in has adequate ventilation.
- Be sure to keep all clothes away from "HOT" materials like molten solder and soldering irons .
- Remove power from all test equipment when it is not being used.
- Use the soldering iron stand to store the iron when not in use.
- Keep the immediate area clean and neat as possible.
- Use established small hand tool safety practices.

LESSON 9: ELECTRONICS

CONTENT

- Benefits of electronics
- Control system operation
- Sensor types
- Actuator types
- Controller components
- Testing electronic systems
- Test equipment

INSTRUCTOR OBJECTIVES

The instructor will:

- Discuss the aplications and advantages of electronic control systems.
- Explain the components of an electronic control system.
- Identify the components of an electronic control system.
- Demonstrate how to test an electronic control system.
- Direct hands-on practice exercises in testing an electronic control system.

TECHNICIAN OBJECTIVES

The technician will:

- Demonstrate knowledge of electronic control systems.
- Demonstrate knowledge of electronic system components.
- Demonstrate knowledge of testing electronic systems.

LESSON 9 GLOSSARY

Actuators	Output devices that receive electrical signal commands and act to change the system being controlled.
Analog Signals	Continuous but changing voltage or current flow.
Closed Loop	Type of control system where an action is taken after the decision. The results of the action are monitored and information is sent back to the controller. The information is then used to make another decision.
Controller	Receives signals from input devices, processes the information, makes decisions and gives commands to output devices.
Digital Signals	Sequences of on or off current flow or voltage.
EPROM	Erasable Programmable Read Only Memory - Basically the same as PROMS except that the memory of an EPROM can be erased.
Fault Message	A message used by some test equipment as a method of telling the technician what problems were found.
Input	Current flow, voltage or power supplied to an electric circuit, system or device.
Input Devices	Send information in the form of analog or digital type electrical signals into controller.
Input/Output Interface	Converts signals that are received from sensors into a electrical command a controller can recognize.
KAM	Keep Alive Memory - Battery powered RAM which maintains the information in the memory if external power is removed.
Microprocessor	The part of a computer which executes the programs that reside in memory, performs calculations and logic operations, and makes decisions on alternate courses of action based on input data.
Open Loop	Type of control system where an action is taken after the decision, but the results of the action are not monoitored or fed back to the controller.
Output	The energy, power, or work produced by a circuit, device or system.
Output Control	Turns external circuits on or off as determined by the operating rules programmed into the computer.
Output Devices	Receive signal commands from a controller and perform action to cause changes in the system being controlled.
PROM	Programmable Read Only Memory - Basically the same as ROMS except they are delivered without program instructions. The user can enter the program instructions with special equipment.
RAM	Random Access Memory - The electronic space in a computer where information or instructions can be entered to control the microprocessor.
Read-Out Control	A electronic circuit which activates a read-out or a display of information to the driver of the vehicle.
ROM	Read Only Memory - The electronic space in a computer where the instructions or programs are entered during manufacture and information cannot be changed or added. Loss of power does not affect ROM.
Sensors	Input devices that send information in the form of electrical signals.

ELECTRONICS

HISTORY

When automobiles first came into being they were relatively simple machines and as time passed they have become more complex. The control and indicator systems initially were mechanical. These were gradually replaced with electrical devices that performed the same function, only better. They also were less expensive to produce and had installation advantages. Electrical devices could be combined into systems for additional advantages over mechanical devices. In recent years electrical devices and systems have been replaced with electronic devices and systems since the electronic items can perform certain functions better than electrical items. This is particularly true in electronic systems used to control and report the various items in the automobile.

BENEFITS OF USING ELECTRONIC SYSTEMS

Control - Electronic devices have a major advantage over electrical systems in the area of controlling things. Electronic systems can be given a far greater number of instructions to follow and the electronic system can make decisions based upon these instructions. The electronic system is digital, it has great mathematical capability and can make decisions based upon rules programmed into its memory. One central "controller" can monitor many conditions on the vehicle, analyze the information and decide what actions are to be taken, then command devices to take the required action and even monitor the results of the action to determine if additional commands should be given.

Cost - Electronic systems are very cost effective for the amount of work they perform. Work performed is mental work not physical work. They are limited in the strength of output current and voltage, therefore they tend to send signals (commands) to other devices which perform the work. The outputs are generally quite low in power and voltage.

Reliability - Due to solid state technology, the amount of actual "parts" that are in a device are minimized for the capability they have. Remember, the more parts you have ...the more that can go wrong. Electronic parts are very reliable.

Speed - Electronic systems can gather information, analyze it and make decisions very quickly. Due to the speed of the system, decision making can be more complex, involve more information to analyze and process which result in better control of the system.

CONTROL SYSTEM OPERATION

The primary use of electronic devices in vehicles is controlling various functions and systems. This takes advantage of their information gathering, analyzing decision making capabilities and allows more complex analysis using larger amount of information. The information can be gathered more quickly, analyzed faster and decisions made more rapidly. The resulting control is much better and can be modified very quickly to meet changing conditions.

The control system consists of three basic areas control system components.

- input devices
- controller
- output devices

The **input devices** are called **sensors**. They send information in the form of electrical signals to the controller. The signals can be analog or digital type signals. **Analog** signals are characterized by changes in voltage or current flow. **Digital signals** are characterized by switching current or voltage ON or OFF. The electronic controller processes information in a digital format, thus analog signals have to be converted from analog to digital. A device called an “A to D converter” is used to accomplish this conversion.

The **controller** receives signals from input devices, processes the information, makes decisions and gives commands to the output devices based upon the input signals and programming within the controller.

The controller has three main areas: input/output interfaces, microprocessor and the memory.

As the signals are received from the sensors, they must be conditioned, that is converted into a signal that the controller can use. The **input/output interface** section performs this function. Analog signals are converted into digital signals and voltage and current levels are changed to a magnitude that is acceptable to the controller. The magnitude of the signals required by the controller are generally small compared to the signals generated by the sensors.

The **microprocessor** section executes instructions that are stored in the memory section. It will get program information and data from the memory, analyze it and issue output commands to the input/output interface section based upon the program commands and the operating/input conditions. Commands issued may not be in the format that the output devices can use so they may have to be conditioned or changed in the input/output interface area. If the actuator requires an analog signal, the digital signal of the controller is changed to an analog signal by an “D to A converter”.

The memory section stores the instructions to be executed by the microprocessor. Data from incoming signals and information generated by the microprocessor is also stored in the memory.

Output devices are called actuators. They receive signal commands from the controller and perform action to cause changes in the system being controlled.

TYPE OF CONTROL SYSTEMS

There are two types of control systems:

- closed loop.
- open loop

In a **closed loop** system an action is taken after the decision. The results of the action are monitored and information is sent back to the controller. The information is then used to make another decision.

In an **open loop** system an action is taken after the decision, but the results of the action are not monitored or fed back to the controller.

There are two types of control: output and read-out.

Output control turns external circuits OFF or ON as determined by the operating rules programmed into the computer.

Read-out control causes a read-out or a display of information to the driver of the vehicle. The display is often integral with the electronic module.

INPUTS TO SYSTEM

Inputs are signals from sensors that are fed into the controller. The sensors measure various operating conditions and give the controller the information it needs to make a decision.

Sensor types There are numerous types of sensors. Each type uses a different principle of operation.

Yes/No - provides yes/no or on/off information on a condition or state of a load, such as the A/C on signal or the engine cranking signal from the ignition switch.

Variable resistor types use a change in resistance to cause a signal change. A coolant temperature sensor, is an example of this type.

The Potentiometer type is used to signal position. This type of sensor uses a reference voltage and a variable resistor. Movement causes the variable resistor to increase or decrease the resistance in the sensor. Knowing the change in voltage from the reference voltage, the position of the component can be determined. Typical application would be to indicate throttle position.

Switches provide an on/off signal. Typical applications are low coolant level switch, low oil level switch and door ajar switch.

Voltage generators create their own signals and indicate a condition. The magnetic pickup of the wheel speed sensor for the anti-lock system is this type of sensor.

Active sensors directly modify the reference voltage.

Passive sensors indirectly modify the reference voltage or do not use reference voltages.

Some examples of sensors are:

1. Low oil pressure sensor
2. Wheel anti-lock sensor
3. Coolant temperature sensor
4. Fuel level sensor

OUTPUTS OF SYSTEM

Outputs are signals sent from the controller to the devices that will perform the action desired. The command signals are determined by the controllers programming instructions and the operating/input conditions received from the sensor inputs. Output devices are called **Actuators**.

ACTUATOR TYPES

There are various types of actuators. Each type uses a different principle of operation.

Yes/No type actuators are used to turn loads off or on. Relays which are used to turn loads on or off is an example of this type of actuator. Remember, the relay contacts can be normally open or normally closed. Example: the fuel pump relay.

Solenoids initiate a control operation by movement of their plunger. A typical use is to control braking pressure in the control valve for the Anti-Lock Brake system.

Read-Outs are solid state devices used to show information to the driver. Instrument panel displays are examples of this type.

Motors are used to position components such as idle speed and fuel mixture control.

ACTUATOR EXAMPLES

Some examples of actuators are:

1. A/C and cooling fan controller
2. Fuel injector solenoids
3. Air control valves

COMPONENTS OF COMPUTER

The controller components are mounted to a printed circuit board (PCB) which is enclosed in a protective housing or case. The PCB board not only holds the components, but also contains the circuits to the components that are mounted on the board.

The microprocessor has two major systems; the COMPUTATION unit which executes the programs that reside in memory, performs calculations and logic operations, and makes decisions on alternate courses of action which are based on input data. The CONTROL unit decodes various instructions and provides timing signals to other parts of the computer.

Different types of memory devices are used in controllers.

RAM (Random Access Memory) can address items in memory in any order requested by the microprocessor. Information can be written to and read from RAM by the microprocessor. Its memory is volatile, that is, it loses the stored data when power is removed from it. RAM is used to store data that will not affect the system operation if it is lost.

ROM (Read Only Memory) is similar to RAM except its memory is Non-Volatile, that is it retains the stored data when power is removed from it. The instructions for the microprocessor are contained in ROM. The instructions for the program are entered into ROM during its manufacture.

Other memory types include **PROMs** and **EPROMs**. These are basically the same as ROMs except they are delivered without program instructions. The user can enter the program instructions. The "P" stands for programmable. The memory of an EPROM can be erased. "E" stands for erasable.

KAM (Keep Alive Memory) is battery powered memory to maintain the information in the memory if power is removed. The microprocessor can store input failure information identified during normal operation of the vehicle for use later in diagnostic routines and adapt some calibration parameters to compensate for changes in the vehicle system.

Various items such as diodes, transistors, resistors, capacitor and so forth are included in the circuit and are attached to the printed circuit board.

TESTING ELECTRONIC SYSTEMS

The two most important points to remember when servicing electronic systems are:

1. Misunderstanding the normal operation often leads to an unnecessary replacement of the component.
2. A component should never be replaced without proper testing and/or diagnosis.

Proper diagnosis and testing are the most important elements in servicing electronic systems.

SELF TEST CAPABILITY

The controllers have a self test capability. Self tests are designed to exercise all system components and identify problem areas. They check for correctness of input and output signals and responses. The controller can record in its memory if there is a problem with itself, the inputs or the outputs.

Self testing, Quick Functional Tests and pinpoint testing are covered extensively in the Shop Manuals for each system.

Be sure to follow the Shop Manual diagnosis and testing procedures before replacing any electronic instrument or related component.

FAULT MESSAGES

Some systems require special test equipment to perform the testing.(Star tester for wheel anti-lock, Message Center Tester for message center) Some testers display messages as a method of telling the technician what problems were found. These **fault messages** are generally displayed to the technician in the form of numbers. Each message will indicate a specific problem. The meaning of the code numbers are given in the Shop Manual for the specific test being performed.

Many systems contain a self test mode that can be accessed by pressing a proper sequence of buttons on the instrument within the vehicle. Various functions can be checked by pressing the buttons one at a time.

Other checks are made by jumpering between selected terminals under the instrument panel. Still others are activated by pressing a button and turning the ignition switch from off to run.

In some instances a special tester may be used to test the system and the fault messages will be displayed on the face of the tester.

CHECKING INPUTS AND OUTPUTS

There may be instances when the system has a problem that is caused by a faulty signal from a sensor or the signal going to the actuator. The cause could be in the sensor/actuator itself, or in the wiring, or connectors. Refer to the shop manual for the various sensor and actuator tests for the system on which you are working. For wiring and connectors, check the wiring harnesses for damage, corrosion, contamination or physical damage. Check the connectors for corrosion, dirt, physical damage, improper installation, connector crimped on insulation and not making contact with wire.

TEST EQUIPMENT

CAUTION: When testing electronic components ALWAYS use a digital meter, NEVER use an analog meter. The amount of current produced by the analog meter during the test could damage the circuitry of the electronic component.

Typical test equipment used to test electronic equipment includes:

- DVOM (Digital Volt/ohmmeter)
- Rotunda Electronic Message Center Tester
- Fuel Gage Tester
- Star tester

CURRENT APPLICATIONS

Typical applications of electronic systems in vehicles are:

- Warning systems
- Message Centers
- Electronics Instrument Clusters
- Digital Speedometers
- Anti-lock brake system
- Engine controls

GLOSSARY

AC	Alternating Current - An electric current which reverses direction in the conductor. The flow in the conductor is created by repeatedly changing the polarity of the source field.
Actuators	Output devices that receive electrical signal commands and act to change the system being controlled.
Alternator	A power generating device which outputs power through the charging system to replenish electricity in the battery.
Ammeter	A test instrument which measures current flow in a circuit.
Amperes	The unit of measure for electric current.
Amp Hours	A system which rates battery capacity to perform work by placing the battery under a specified load and measuring the time required to discharge.
Amp-type Connectors	Connectors which have a bridge on the pin half and latching legs on the socket half.
Analog Meter	An electrical test meter which uses a spring-loaded needle and a magnetic field to indicate a circuit value on the meter scale.
Analog Signals	Continuous but changing voltage or current flow.
Base Voltage	The voltage measurement across the battery terminals with the ignition switch and all accessories turned off.
Bi-Metal Strip	Two strips of metal that will expand at different rates when heated.
Break Before Make	The wiper of a switch does not close a circuit before it opens the preceding circuit.
Broken Wires	A physical separation in conductive wire.
Buss	Point of power distribution.
Case Grounds	Used when the component has a metal case and is attached to a well grounded part of the vehicle.
Circuit Breaker	Device which protects circuit from overload.
Closed Circuit	A complete path from the power source to an electrical load or device, and back to the power source.
Closed Loop	Type of control system where an action is taken after the decision. The results of the action are monitored and information is sent back to the controller. The information is then used to make another decision.
Cold Cranking Amps	A system which rates a battery by the amount of current it can deliver at zero degrees F.
Conductors	A substance in which an electric current will flow. Current flow is possible because of many free electrons in the substance.
Continuity Tester	A device used to test electrical circuits for a complete circuit path. A light bulb and dry cell battery are contained in the probe handle. The bulb will light when the two ends of the tester are connected to a complete, unpowered circuit.
Controller	Receives signals from input devices, processes the information, makes decisions and gives commands to output devices.
Current	The movement of electrons in a conductor when electromotive force is applied.

GLOSSARY

Cut Wire Reference	Used to show current flow from power to ground.
Cycling Circuit Breaker	Circuit protection device which opens a circuit when an overload occurs and makes the circuit when overload ceases.
DC	Direct Current
Delta Winding	A stator winding that resembles the Greek letter Delta. In the Delta winding, each coil winding end is connected to the end of another coil winding end to form a closed series circuit.
Digital Meter	An electrical test meter which displays the measured value in numeric form.
Digital Signals	Sequences of on or off current flow or voltage.
Diode	A semiconductor which will only permit current to flow in one direction.
DVOM	Digital Volt/Ohm Meter
Electrolyte	The nonmetallic substance in a battery which promotes a chemical reaction between the two electrodes.
EPROM	Erasable Programmable Read Only Memory - Basically the same as PROM except that the memory of an EPROM can be erased.
EVR External Voltage Regulator	A regulator that is not an integral component of the alternator.
EVTM	Electrical and Vacuum Troubleshooting Manual - Contains electrical and vacuum systems drawn in a clear and simple way to make troubleshooting easier.
Extremely High Resistance	Resistance so high that current cannot flow.
Fault Message	A message used by some test equipment as a method of telling the technician what problems were found.
Fixed Value Resistors	Resistor having a specific value of resistance.
Flasher	A time delay switch that opens after a predetermined time, but closes and then reopens, continuing the cycle until the power is removed.
Ford Blade Connectors	Connectors that have T-shaped cavities in the mating end of the socket half of the shell.
Fuse	A protective device placed in a circuit which will melt and discontinue current flow if an overload condition exists.
Fuse Block	Location of fuses and power to circuits.
Fuse Link	A protective device placed in a circuit which will melt and discontinue current flow if an overload condition exists.
Ganged Switch	A switch having two or more wipers that operate in unison from a single control.
Gauge	Size of a conductor wire.
Ground	The portion of a circuit that completes the . path to the power source after the load.
Hinged Pawl Switch	Makes or breaks the current in a single conductor or circuit.

GLOSSARY

IAR	Integral Alternator/Regulator - A solid state voltage regulator located within the alternator.
Induction	The creation of an electric current in a conductor by passing it thru the field of a magnet or a current carrying conductor.
Inductive Ammeter	An ammeter which utilizes the principle of magnetic induction to measure current flow in an electrical circuit. This type of meter is typically used for measuring large currents such as starting and charging systems.
Input	Current flow, voltage or power supplied to an electric circuit, system or device.
Input Devices	Send information in the form of analog or digital type electrical signals into a controller.
Input/Output Interface	Converts signals that are received from sensors into an electrical command a controller can recognize.
Insulator	A substance in which current will not flow because of a lack of free electrons.
Internal Locking Finger Connectors	Connections that have fingers which are clearly visible in the contact cavities in the shells mating ends.
Internal Shunt Ammeter	An ammeter which is connected in series with the circuit to be tested. These meters are used typically in circuit tests where current flow is less than 10 amps.
Jumper Wire	A length of wire with probes or clips at each end used to bypass a portion of a circuit.
KAM	Keep Alive Memory - A battery powered RAM which maintains the information in the memory if external power is removed.
Load	A device in an electrical circuit that converts current flow to heat, light or motion.
Load Test	The voltage measurement across the battery terminals with the engine running and all major accessories (heater, A/C and high beams) turned on.
Locking Wedge Connectors	Connectors that have red or brown wedge release tabs which are visible through windows in the connector shell.
Loose Connections	A connector which loses physical contact with its mate disrupting current flow.
Magnetic Field	The field surrounding a magnet or current carrying conductor.
Make Before Break	The wiper of the switch closes a circuit before it opens the preceding circuit.
Mercury Switch	Contains a capsule partially filled with mercury which makes or brakes contact when switch is tipped.
Microprocessor	The part of a computer which executes the programs that reside in memory, performs calculations and logic operations, and makes decisions on alternate courses of action based on input data.
Momentary Contact Switch	Has a spring-loaded contact that keeps it from making (or breaking) the circuit except when pressure is applied to the button.
No Load Test	The voltage measurement across the battery terminal with the engine running but no accessories turned on.

GLOSSARY

Non-Cycling Circuit Breaker	Circuit protection device which opens a circuit when an overload occurs. Power must be removed to reset the breaker.
Normally Open	When the rest position of the switch is to open the circuit.
Normally Closed	When the rest position of the switch is to close the circuit.
OASIS	On-line Automotive Service Information System - A computer based service information system designed to assist service technicians with difficult vehicle diagnosis and repair problems.
Ohmmeter	An electrical test instrument used to measure the resistance in an electrical circuit.
Ohms	The unit of measure for resistance to current flow.
Ohm's Law	A series of formulas which are used to determine the values in an electrical circuit. Any two of the values can be multiplied or divided to determine the third unknown value.
Open Circuit	A condition in which the circuit path is broken and current cannot flow.
Open Internally (Burn Out)	A physical separation causing a lack of continuity in a load.
Open Loop	Type of control system where an action is taken after the decision, but the results of the action are not monitored or fed back to the controller.
Output	The energy, power, or work produced by a circuit, device or system.
Output Control	Turns external circuits on or off as determined by the operating rules programmed into the computer.
Output Devices	Receive signal commands from a controller and perform action to cause changes in the system being controlled.
Over Voltage Test	This test is made if the No Load test was more than 2.5 volts greater than the Base voltage in either a EVR or IAR alternator system.
Parallel Circuit	An arrangement that provides separate power supplies and ground paths to several loads.
Potentiometer	A type of variable resistor.
Printed Circuit Connectors	Connectors that have terminals which are rounded at the ends and the ends are visible at the mating end of the shell.
PROM	Programmable Read Only Memory - Basically the same as ROMS except they are delivered without program instructions. The user can enter the program instructions with special equipment.
RAM	Random Access Memory - The electronic space in a computer where information or instructions can be entered to control the microprocessor.
Read-Out Control	An electronic circuit which activates a read- out or a display of information to the driver of the vehicle.
Rectification	Changing alternating current, generated by the alternator, into direct current.
Reference Wires	Reference wires are used to complete wiring shown on another page of the wiring diagram.

GLOSSARY

Relay	Switch that uses a small current flow to control a larger current.
Remote Grounds	Remote grounds are used where the component itself is not grounded and is shown in the wiring on the wiring diagram.
Resistance	A substance in which current flows at a limited rate. Resistors have fewer free electrons than conductors.
Resistors	Devices used to limit current flow in a circuit due to their high resistance to current flow.
Resistor Wires	Wire having a high resistance to current flow. Rated in ohms per foot.
Rheostats	A type of variable resistor.
ROM	Read Only Memory - The electronic space in a computer where the instructions or programs are entered during manufacture and information cannot be changed or added. Loss of power does not affect ROM.
Self Powered Test Light	A device used to check for continuity in a circuit. It has an internal battery which supplies current to the circuit being tested. The test light will come on if continuity exists. It is sometimes called a continuity tester.
Semiconductor	A material that can be made to conduct or not to conduct electricity
Sensors	Input devices that send information in the form of electrical signals.
Series Circuit	An arrangement in which current must flow through one load before another. Each load shares the power supply with the other loads in the circuit.
Series-Parallel Circuit	An arrangement that combines two or more loads in parallel, with one or more loads in series.
Shop Manual	Provides information covering normal service, repairs and maintenance for multiple vehicle lines. The information is very detailed and is the best initial source of information.
Short Circuit	A condition in which a path is provided around the circuit load to ground.
Shorts Internal to Loads	The physical contact of conductors internal to a load which can cause burn out or strange operational characteristics.
Solenoids	Electromagnets with movable cores which are used to translate electrical current flow into mechanical movement.
Specification Book	Contains service specifications for all vehicle lines.
Stepped Resistors	Have two or more fixed resistance values, which can be selected by connecting wires to the various taps on the resistor.
Sulphated	A condition which will no longer allow a lead/acid battery to hold a charge.
Switch	Off-On controls in a circuit.
Tang-Type Connectors	Connectors that have uniquely shaped latching tongues with plastic springs.
Temperature-Sensitive Switch	Contains a bi-metal element which makes or breaks a circuit when the switch is heated.
Thermal Limiter	Temperature sensitive device which protects circuit from overload.

GLOSSARY

Thermocouple	A device which generates electricity when it is heated.
Time Delay Switch	Opens after a predetermined time, and stays open as long as the power is applied to the switch.
TSB	Technical Service Bulletins - Provides the latest service information, clarification of information, information not available at the time manuals were published, revised service procedures, customer problems and more. TSB's are published twice a month.
TSB Index	Technical Service Bulletin Index - Provides a quick and easy way of finding necessary technical service bulletin information.
Under Voltage Test	This test is made if the No Load test was less that 0.5 volts above the Base voltage in either the EVR or IAR alternator system.
Variable Resistors	Have a range of resistances available through two or more taps and a movable control.
Volts	The unit of measure for electrical pressure or electromotive force.
Voltage	The electrical pressure in a circuit.
Voltage Drop	The change in electrical pressure between any two points in a circuit. The amount of voltage drop between two points in a circuit will be determined by the resistance of the circuit loads and the number of loads in a circuit.
Voltmeter	An electrical test meter which measures electrical pressure (EMF).
12 Volt Test Light	A device used to check for voltage in a circuit. A 12 volt bulb is located in the probe handle, and will light when one end of the device is grounded and the other is connected to a power source.
Wiper	Movable portion in a variable resistor or switch.
Wiring Diagrams	Wiring diagrams present the wiring schematics for the complete vehicle.
Wiring Harness	Bundle of wires wrapped together for consolidation purposes.
Wiring Loom	Another name for a wiring harness.
Wire to Ground Short	The physical contact of a current carrying wire and a ground which can cause the circuit to overload.
Wire to Wire Shorts	The physical contact of two conductive wires which can cause strange operational characteristics in the circuit due to current flow through alternate paths.
Wye Winding	A stator winding that resembles the letter Y. In the Wye winding a pair of coil windings form a series circuit while the third coil is neutral.

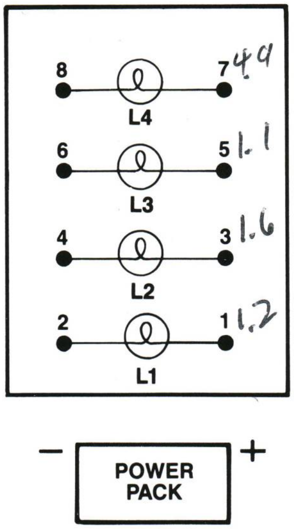
WORKSHEETS

BASIC CIRCUIT CONSTRUCTION FOR SERIES CIRCUITS

TECHNICIAN NAME: ____________________

4.4
1.1
1.6
1.2
8

INSTRUCTIONS — Using 4 bulb light board and power pack set to 12 volts and set amps fully clockwise perform the following steps. Have instructor check your work and initial this worksheet after each step. Important — Verify Bulbs L1, L2, & L3 are all type 1156.



Step 1 — Connect power source across bulb L1 (terminals 1 and 2)

— Observe brilliance of bulb Bright

Instructor D P Piper 520

Step 2 — Connect bulbs L1 and L2 in series (positive to terminal #1, jumper 2 to 3, jumper 4 to negative)

— Observe brilliance of bulbs Dim

— Why are they not as bright as in step 1 because of a higher resistance from another bulb

Instructor ____________________

Step 3 — Connect bulbs L1, L2 and L3 in series (positive to terminal #1, jumper 2 to 3, jumper 4 to 5, jumper 6 to negative)

— Observe brilliance of bulbs Dimmer than step 2

— Why are they not as bright in step 2 because of a high resistance from another bulb

Instructor ____________________

Piper

$$\begin{array}{r} 10.\overset{2}{8}7 \\ .66 \\ .44 \\ .38 \\ \hline 12.39 \end{array}$$

1. 10.87
2. ~~.66~~
3. ~~.44~~
4. .38

[illegible]

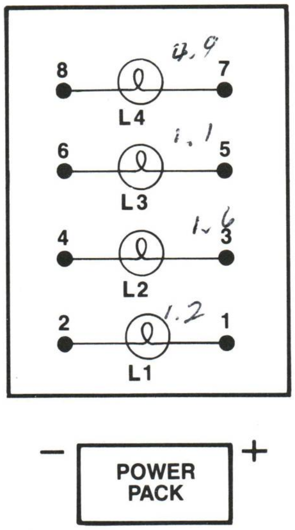
$$\begin{array}{r} 13 \\ 9\overline{)12} \\ 9 \\ \hline 30 \end{array}$$

WORKSHEET 9

BASIC CIRCUIT CONSTRUCTION OF PARALLEL CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS — Using 4 bulb light board and power pack set to 12 volts and set amps fully clockwise, build parallel circuits per the following steps. Have instructor check your work and initial your worksheet after each step.



Step 1 — Connect power source across bulb L1 (terminals 1 and 2)

— Observe brilliance of bulb Bright

— How does this differ from series Doesn't

Instructor ______________

Step 2 — Connect bulb L2 in parallel with bulb L1 (positive to terminal 1, jumper 1 to 3, jumper 2 to 4, jumper 2 to negative)

— Observe brilliance of bulbs Bright (L1) Bright (L2)

— How does this differ from 2 bulbs in series Both

Bright Both bulbs recieve same amoung of ~~current~~ Volted circuit

Instructor ______________

Step 3 — Connect bulbs L1, L2 and L3 in parallel (positive to terminal 1, jumper 1 to 3, jumper 3 to 5, jumper 6 to 4, jumper 4 to 2, jumper 2 to negative)

— Observe brilliance of bulbs Bright (L1) Bright (L2) Bright (L3)

— How does this differ from 3 bulbs in series all three still

Bright bulbs recieve same Voltage.

Instructor ______________

$$R = \frac{12}{\frac{12}{R} + \frac{12}{R} + \frac{12}{R} + \frac{12}{R}}$$

$$\begin{array}{r} 38 \\ \times 4 \\ \hline 136 \end{array}$$

$$\begin{array}{r} 3 \\ 38\overline{)120} \\ 114 \\ \hline 60 \end{array}$$

WORKSHEET 10

BASIC CIRCUIT CONSTRUCTION OF SERIES — PARALLEL CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS — Using 4 bulb light board and power pack set to 12 volts and set amps fully clockwise, build series parallel circuit per the following steps. Have instructor check your work and initial your worksheet after each step.

Step 1 — Connect power source across bulb L1 (terminals 1 and 2)

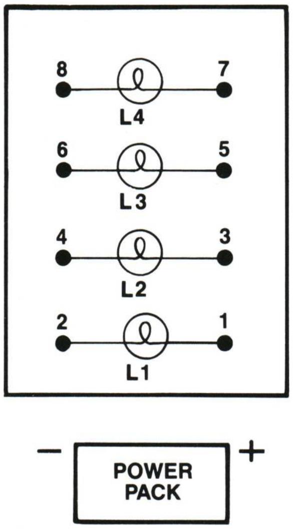
— Observe brilliance of bulb L1 Bright

Instructor ______________

Step 2 — Connect bulbs L2 and L3 in parallel with bulb L1 (positive to terminal 1, jumper 2 to 3, jumper 3 to 5, jumper 6 to 4, jumper 4 to negative)

— Observe brillance of bulbs Bright (#1) Dim (#2) Dim (#3)

Instructor ______________



14.31

.16

.16

.52

D F Piper

520

14.31
.16
.16
.52
15.15

RESISTANCE MEASUREMENT

TECHNICIAN NAME: ____________________

INSTRUCTIONS — Measure the resistance of each resistor on the resistor board with both a DVOM and VOM. Fill in the chart below.

DVOM SCALE

DVOM Reading Resistor	200	2000	20k	200k
1	1.3	2	00	00
2	4.5	5	00	00
3	68.3	69	.07	00
4	178.3	178	.18	.2
5	over range +1	221	.22	.2
6	—	390	.39	.4
7	—	674	.67	.07
8	—	1492	1.44	1.5
9	—	over rang +1	3.60	3.6
10	—	—	14.92	14.9
11	—	—	over rang +1	99.6
12	—	—	+1	151.9

VOM SCALE

VOM Reading Resistor	R × 1	R × 100	R × 1000
1	.75	0	0
2	3.	10	0
3	50	60	0
4	150	170	0
5	175	200	100
6	300	400	200
7	500	650	500
8	+1	1500	1200
9	+1	3500	3000
10	+1	15,000	14,000
11	+1	50,000	90,000
12	+1	over +1	150,000

520

RESISTANCE MEASUREMENTS IN SERIES CIRCUITS

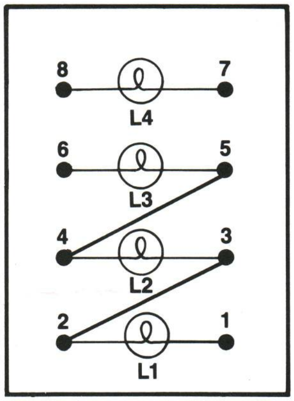
TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 — Measure resistance of each load with a VOM and DVOM.

	VOM	DVOM
Pin 1-2	.9	1.0
Pin 3-4	.8	1.0
Pin 5-6	1.2	1.7
TOTAL	2.8	3.7

Step 2 — Build series circuit per Diagram, but do not hook up power supply. Have instructor check your circuit and initial this sheet before you proceed.



D F Piper
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Instructor ______________________

Step 3 — Measure the total resistance of the circuit with a VOM and DVOM. Pin 1 to Pin 6

	VOM	DVOM
Total Resistance	2.8	3.7

Step 4 — Compare total of individual resistances in Step 1 with total circuit resistance in Step 3.

____ Larger

____ Smaller

[✓ Same]

Step 5 — Have instructor check your measurements and answer, then initial this sheet.

Instructor ______________________

Step 6 — Proceed to Worksheet 13, USING SELF-POWERED TEST LIGHT IN SERIES CIRCUIT.

SELF-POWERED TEST LIGHT MEASUREMENTS
IN
SERIES CIRCUITS

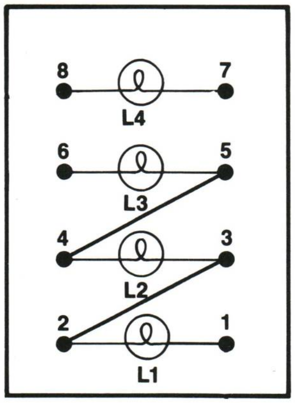
R. Piper

520

TECHNICIAN NAME: ______________________

INSTRUCTIONS

Step 1 — Use the series circuit you built for Worksheet 12.



Step 2 — Connect the test light as indicated and record if the test light is ON or OFF.

	ON	OFF
Pin 1-2	0 ✓	
Pin 1-4	✓	
Pin 1-6	✓	

Step 3 — Cause an open circuit by removing a jumper wire from terminal 5.

Step 4 — Connect the test light as indicated and record if the test light is ON or OFF.

	ON	OFF
Pin 1-2	✓	
Pin 1-4	✓	
Pin 1-6		✓

Step 5 — Explain the results of Step 4.

Pin 1 to 6 to an open circuit because 4 to 5 is disconnected or
ope

Step 6 — Have the instructor check your results and explanation and initial this sheet.

Instructor ______________________

Step 7 — Proceed to Worksheet 14, VOLTAGE MEASUREMENTS IN SERIES CIRCUITS.

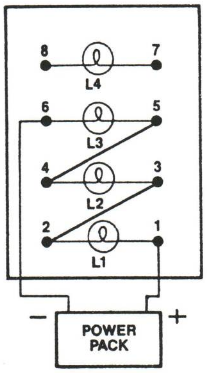
WORKSHEET 14

VOLTAGE MEASUREMENTS
IN
SERIES CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 — Use the series circuit you built for Worksheet 13, set power pack to 12 volts and set amps fully clockwise and connect to circuit.



Step 2 — Measure the voltage across each load using a VOM and a DVOM. (Remember power to the circuit must be ON.)

	VOM	DVOM
Pin 1-2	4 V	3.81 V
Pin 3-4	4 V	3.83 V
Pin 5-6	4 V	4.37 V

Step 3 — Measure voltage across bulbs L1 and L2.

	VOM	DVOM
Pin 1-4	8 V	7.67 V

Step 4 — Measure voltage across bulbs L1, L2, and L3.

	VOM	DVOM
Pin 1-6	12 V	12 V

Step 5 — What happens to voltage reading as you measure across more loads?

✓ increases
_____ decreases
_____ stays the same

Step 6 — Have the instructor check your measurements and answers, and initial this sheet when you are completed.

Instructor ______________________

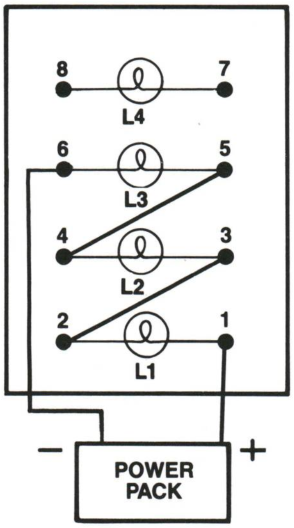
Step 7 — Proceed to Worksheet 15, CURRENT MEASUREMENTS IN SERIES CIRCUITS.

CURRENT MEASUREMENTS IN SERIES CIRCUITS

TECHNICIAN NAME: ____________________

INSTRUCTIONS

Step 1 — Use the series circuit you built for Worksheet 14, set power pack to 12 volts and set amps fully clockwise and connect to circuit.



Step 2 — Measure current going into each load using a VOM and a DVOM. (Remember power to the circuit must be ON.)

	VOM	DVOM
PIN 1	.54 A	.57 A
PIN 3	.54 A	.57A
PIN 5	.54 A	.57A

Step 3 — Does the current going to each load:

___ increase
___ decrease
_✓_ stay the same

Step 4 — Have the instructor check your measurements and answers, then initial this sheet.

Instructor ____________________

Step 5 — Proceed to Worksheet 16, 12 volt test light in series circuits.

D Piper

12 VOLT TEST LIGHT IN SERIES CIRCUITS

TECHNICIAN NAME: ____

INSTRUCTIONS

Step 1 — Use the series circuit from Worksheet 15.

Step 2 — Connect a 12 volt test light across each load and record if the test light is ON or OFF. (Remember that since the 12 volt test light is not self-powered, the power to the circuit must be ON. Set power pack to 12 volts and set amps fully clockwise.)

	ON	OFF
Pin 1-2	✓	
Pin 3-4	✓	
Pin 5-6	✓	

Step 3 — Connect the test light across each load to ground. Record if the test light is ON or OFF.

	ON	OFF
Pin 1 — GRD	✓	
Pin 3 — GRD	✓	
Pin 5 — GRD	✓	

Step 4 — Cause an open circuit by removing a wire from pin 3 and connect the test light across each load and record if the test light is ON or OFF.

	ON	OFF
Pin 1-2		✓
Pin 3-4		✓
Pin 5-6		✓

Step 5 — Connect the test light across each load to ground. Record if the test light is ON or OFF.

	ON	OFF
Pin 1 — GRD	✓	
Pin 3 — GRD		✓
Pin 5 — GRD		✓

Step 6 — Explain the results of Step 5.

Because you have an open circuit from pin 2 to 3

Step 7 — Have the instructor check your results and explanation, then initial the sheet.

Instructor ____________________

D P Piper

ANSWER SHEET
ELECTRICAL MEASUREMENT TERMS

TECHNICIAN NAME: ______________________

INSTRUCTIONS

1. Using the Rotunda Digital Multimeter as reference, determine which meter scale should be used to measure the following values:

Value	Meter Scale
a. 14,000 Ohms	20 K Ω
b. .015 Volts	[illegible] 200 mV
c. 10,000,000 Ohms	20 M

2. Match the values in the left column with their metric equivalent from the right column.

F	a. 10,000 volts	a. 250mA
H	b. 25,000,000 ohms	b. 2.5KΩ
G	c. .10 volts	c. 25μA
A [illegible]	d. .25 amps	d. 25KΩ
C [illegible]	e. .000025 amps	e. 1Kv
B	f. 2500 ohms	f. 10Kv
D	g. 25,000 ohms	g. 100mv
E	h. 1,000 volts	h. 25MΩ

3. Fill in the missing values for each row:

5,000	Ω	=	5	KΩ	=	.005 [illegible]	MΩ
20,000	Ω	=	**20**	KΩ	=	.02 [illegible]	MΩ
5,500,00	Ω	=	5500	KΩ	=	**5.5**	MΩ
3	V	=	[illegible] 3000	mV	=	3,000,000 [illegible]	μV
[illegible] .07	V	=	**70**	mV	=	~~.07~~ [illegible] 70,000	μV
.002	V	=	[illegible] 2	mV	=	**2,000**	μV
9	A	=	9000	mA	=	9,000,000	μA
.06	A	=	**60**	mA	=	60,000	μA
.0055	A	=	5.5	mA	=	**5,500**	μa

Instructor ______________________

D F Piper

RESISTANCE MEASUREMENTS IN PARALLEL CIRCUITS

TECHNICIAN NAME: ____________________

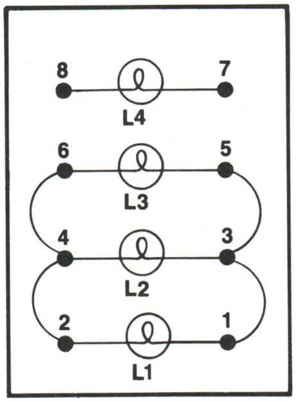
INSTRUCTIONS

Step 1 — Measure the resistance of each bulb on the light board using a VOM and DVOM.

	VOM	DVOM
PIN 1-2	1.0	1.2
PIN 3-4	.8	1.2
PIN 5-6	1.6	2.3

Step 2 — Build parallel circuit per below figure, but do not connect power supply. Have the instructor check your circuit and initial this sheet before you proceed.

Instructor ____________________



Step 3 — Measure the resistance of the total circuit.

	VOM	DVOM
PIN 1-2 Total circuit resistance	.4	.5

Step 4 — Is the total circuit resistance larger, smaller or the same as the resistance of the bulbs?

____ larger
✓ smaller
____ same

Step 5 — Compare the total resistance of the series circuit you measured earlier (Worksheet 12) with the total resistance of the parallel circuit. Which circuit has the larger resistance?

✓ series circuit
____ parallel circuit

Step 6 — Have the instructor check your measurements and answers and initial this sheet.

Instructor ____________________

Step 7 — Proceed to Worksheet 19, VOLTAGE MEASUREMENTS IN PARALLEL CIRCUITS.

VOLTAGE MEASUREMENTS IN PARALLEL CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 — Using the circuit from Worksheet 18, set power pack to 12 volts. Set amps fully clockwise and connect to circuit.

Step 2 — Measure the voltage across each load with a VOM and DVOM. Remember power to the circuit must be ON.

	VOM	DVOM
PIN 1-2	12.0 V	12.07
PIN 3-4	12.0 V	12.0
PIN 5-6	12.0 V	12.0

Step 3 — Compare the voltage across the source to the voltage across each load. Is the source voltage:

____ larger

____ smaller

✓ the same

Step 4 — Have the instructor check your measurements and answers and initial this sheet.

Instructor ______________________

Step 5 — Proceed to Worksheet 20, CURRENT MEASUREMENTS IN PARALLEL CIRCUITS.

CURRENT MEASUREMENTS IN PARALLEL CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 — Using circuit from Worksheet 19; set power pack to 12 volts. Set amps fully clockwise and connect to circuit.

Step 2 — Measure the current in each branch going into the load using the VOM and DVOM. Remember power to the circuit must be ON and the meter connected in series with the load.

	VOM	DVOM
PIN 1	~~3~~ 1	~~2.94~~ .98
PIN 3	~~2~~ 1	~~1.96~~ .98
PIN 5	~~1~~ 1	~~.98~~ .98

Step 3 — Does the current in each branch:

- ____ increase
- ____ decrease
- _✓_ stay the same

Step 4 — Compare these current measurements with the measurements you made for the series circuits (Worksheet 15). Is the current in parallel circuits going into each load:

- _✓_ larger
- ____ smaller
- ____ the same

Step 5 — Add the current going into all the branches. 3

Step 6 — Measure the current for the total circuit (3) and compare it to the total for all the branches. Is the total circuit current:

- ____ larger
- ____ smaller
- _✓_ the same

Step 7 — Have the instructor check your measurements and answers and initial this sheet.

INSTRUCTOR ______________

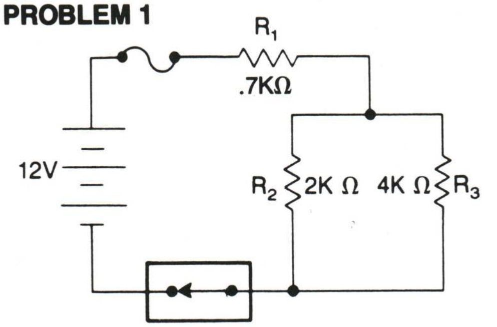
WORKSHEET 21A

WORKSHEET
FOR
OHM'S LAW

TECHNICIAN NAME: ______________________________

INSTRUCTIONS: Determine the Total Resistance (R_T) and currents for the following circuits.
NOTE: STATE ALL ANSWERS IN KΩ OR ma (MILLIAMPS)

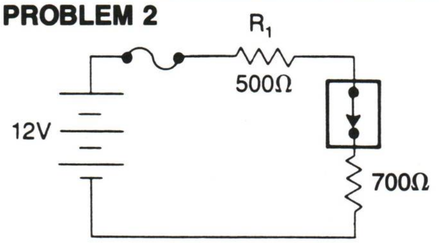
PROBLEM 1



K = [illegible] x 1000
Ω = [illegible]
ma = [illegible] ÷ 1000
A = ~~1000~~ [illegible] cant

R_T = ~~2.03 K~~Ω 2 kΩ
A = 6 mA

PROBLEM 2

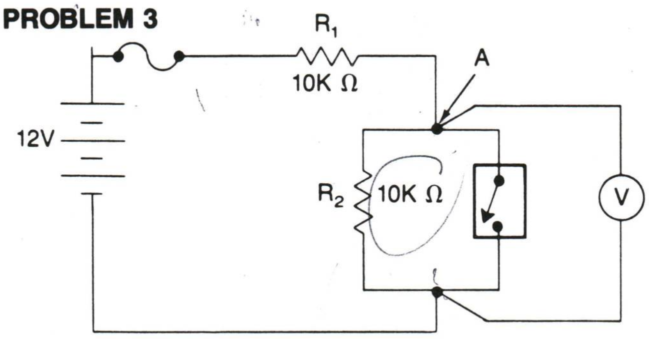


R_T = 1.2
A = 10 mA

1200

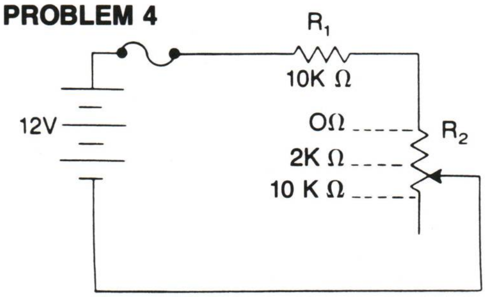
$1.2\overline{)12.0}$ 10

PROBLEM 3



R_T (with switch open) 20 K
R_T (with switch closed) 10 K
A (with switch open) .6 m
A (with switch closed) 1.2 m
Voltage Reading at point A:
with switch open 6 V
with switch closed 0 V

PROBLEM 4



R_T (with R_2 at 0Ω position) 10 K
R_T (with R_2 at 2KΩ position) 12 K
R_T (with R_2 at 10KΩ position) 20 K
A (with R_2 at 0Ω position) 1.2 m
A (with R_2 at 2KΩ position) 1 m
A (with R_2 at 10K Ω position) ~~[illegible] m~~ .6

INSTRUCTOR ______________

CIRCUIT CONTROL DEVICES
WARNING BUZZER CIRCUIT

TECHNICIAN NAME: ____________________

INSTRUCTIONS

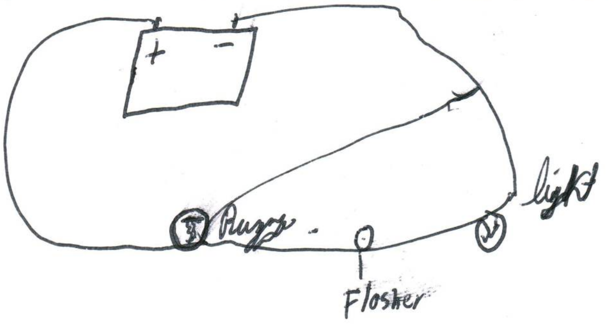
Step 1 — Use loud test board and power pack.

Step 2 — Energize circuit and observe results.

Step 3 — Write your observations here:

Made Buzzer buzzed & light lit

Step 4 — Draw the circuit, identify each component and state its purpose in the circuit.



Step 5 — Have the instructor review your answers and initial this sheet.

INSTRUCTOR ____________________

CIRCUIT CONTROL DEVICES
HAZARD WARNING CIRCUIT

TECHNICIAN NAME: ____

INSTRUCTIONS

Step 1 — Use flasher board and light board to build a circuit to demonstrate the operation of a hazard warning circuit. Remember, if one bulb is disconnected, all others must operate.

Step 2 — Demonstrate circuit operation to instructor with:

1 Bulb	Instructor ____________________
2 Bulbs	Instructor ____________________
3 Bulbs	Instructor ____________________

Step 3 — Demonstrate to instructor that one bulb disconnected will not cause the other lights to go out.

Instructor ____________________

CIRCUIT CONTROL DEVICES
HEADLIGHT CIRCUIT

TECHNICIAN NAME: ____

INSTRUCTIONS

Step 1 — Use a headlight switch and 2 light boards to build a vehicle lighting circuit to demonstrate:

A. Left and right headlight

B. Left and right parking light

C. Dome light

D. Dash light

Step 2 — After completing the circuit demonstrate to the instructor:

A. Headlights off and on

B. Parking lights off and on

C. Dome light off and on

D. Dash light off and on and dimming.

Instructor ____________________

ELECTRICAL COMPONENT IDENTIFICATION AND FEATURES

TECHNICIAN NAME: ____________________

INSTRUCTIONS

Each component on the bench has been assigned a letter. Identify which type of control device it is by checking the proper row in the table.

If the component is a switch, indicate if it is Normally Open or Normally Closed, the number of Poles and the number of Throws. If it is Ganged, indicate if it is a Make Before Break or Brake Before Make type.

Use a DVOM if required.

CONTROL DEVICE	COOLANT TEMP. SWITCH	BLOWER MOTOR RESISTOR	NEUTRAL START SWITCH	HORN RELAY	FUEL PUMP RELAY	HEADLIGHT SWITCH	STARTER RELAY	OIL PRESSURE SWITCH	POWER WINDOW SWITCH
	A	B	C	D	E	F	G	H	I
RESISTOR Fixed									
Variable						X			
Stepped		X							
SWITCH Normal open	X		X	X	X	X	X		X
Normal closed								X	
# of poles	1		2	1	1	1&3	1	1	1
# of throws	1		2	1	1	1&2	1	1	2
Ganged — yes						X			
— no			X						
Make before Break						X		X	
Break before Make			X						
Hinged pawl									
Momentary contact			X						X
Mercury switch									
Temperature sensitive	X								
Time delay									
RELAY				X	X				
SOLENOID							X		

MULTI POLE/MULTI THROW SWITCH OPERATION

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Make continuity check of ignition switch in various positions and fill in charts below.

MAKE CHECK FROM BATTERY TERMINAL

Circuit	Terminal	Switch Position				
		Accy	Lock	Off	Run	Start
Bulb Test	P1	off	off	off	off	off
Bulb Test	P2	off	off	off	off	off
Starter Relay	ST	off	off	off	off	on
Ignition Coil	12	off	off	off	off	on
Ignition Coil	11	off	off	off	on	off
Turn Signal Back Up Lights	A2	off	off	off	on	off
Accessories	A1	on	off	off	on	off

MAKE CHECK FROM GROUND TERMINAL

Circuit	Terminal	Switch Position				
		Accy	Lock	Off	Run	Start
Bulb Test	P1	off	off	off	off	on
Bulb Test	P2	off	off	off	off	on
Starter Relay	ST	off	off	off	off	off
Ignition Coil	12	off	off	off	off	off
Ignition Coil	11	off	off	off	off	off
Turn Signal Back Up Lights	A2	off	off	off	off	off
Accessories	A1	off	off	off	off	off

Instructor ______________________

CUSTOMER WIPER PROBLEM

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Using the Service Literature for the vehicle available, perform the following activities.

Step 2 Customer states that the windshield wipers will not return to the park position.

a. List possible problem sources?

Motor, switch, wiring or govener assembly

b. List corrective action?

Perform parking test

c. What is the ground number for the wiper switch?

G 201 - EVTM

d. Mark the wire with masking tape and show it to the instructor.

589 orange to interval goventer out terminal 57 BK Through
splice S303 then splice 302 to ground G201
S303 Near windshield wiper T/O
S302 Near T/O to G201 / G201 left hand fender apron

e. List the service literature sources you used to answer this question.

EVTM & Shop Manual

Instructor ______________________

CUSTOMER HORN PROBLEM

TECHNICIAN NAME: ____________________

INSTRUCTIONS

Step 1 Using the service literature for the vehicle available, perform the following activities.

Step 2 Customer states that both horns do not work.

a. The problem could be a connector. Identify the connector (C299) and find its location on the vehicle. Mark the connector with masking tape & show the instructor.

Behind ant of I/P. on I/P Brac

b. Identify the circuit number and the wire color. Find the wire, mark it with a piece of masking tape and show it to the instructor so he can verify that you found the correct wire.

Circuit N.O. 1 DB

c. The problem could also be a blown fuse. Identify the fuse number 12.

The fuse rating 20 A.

Remove the fuse & show it to the instructor.

Instructor ____________________

POWER WINDOW CIRCUIT

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Using the wiring diagram provided in the EVTM and the power window demo, complete the wiring of the power window circuit. Then apply power to the circuit and operate the power window motors. When completed notify the instructor so he can check the operation.

a. From driver's seat:

LF window ____________

RF window ____________

LR window ____________

RR window ____________

Locking function ____________

b. Individual window control

RF window ____________

LR window ____________

RR window ____________

Instructor ____________________

INTERMITTENT WIPER CIRCUIT

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Using the wiring diagram provided in the EVTM and the intermittent wiper motor demo, complete the wiring of the wiper system circuit. Then apply power to the circuit and operate the wiper motor. When completed notify the instructor so he can check the operation.

a. Wiper motor operation

Hi speed ____________

Low speed ____________

Intermittent ____________

Instructor ____________________

IAR ALTERNATOR BENCH TESTS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Find the bench tests for an IAR alternator in the shop manual and perform the following tests:

Step 2 RECTIFIER AND STATOR GROUNDED TEST

What was the resistance you measured? 7 Ω

What happened when you reversed the leads? it over scale +1

Why did it happen? Becase the diode block current flow to

Step 3 FIELD OPEN OR SHORT CIRCUIT TEST

What was the resistance you measured? 7-12 Ω

What happened when you reversed the leads? same

Why did it happen? beacuse it is a complete circuit to grot

Step 4 RECTIFIER ASSEMBLY TEST

What was the resistance you measured? 9 Ω

What happened when you reversed the leads? had high resist

Why did it happen? Because diode Block current flow in in direction and also let current flow in other direct

Step 5 RADIO SUPPRESSION CAPACITOR OPEN OR SHORT TEST

What was the resistance you measured? 1080 Ω

What happened when you reversed the leads? it went infinit

Why did it happen? Becaus flow is in one directo Becouse of diod

Instructor ______________________________

EVR ALTERNATOR BENCH TESTS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1

Find the bench tests for an EVR alternator in the shop manual and perform the following tests:

Step 2 RECTIFIER AND STATOR GROUNDED TEST

What was the resistance you measured? 7 Ω

What happened when you reversed the leads? it was ovr scal +1

Why did it happen? because diodes Block current flow to one direction

Step 3 FIELD OPEN OR SHORT CIRCUIT TEST

What was the resistance you measured? 0 9 Ω

What happened when you reversed the leads? same

Why did it happen? because all you ar check are continuity threw Brush to rotor Back to ground

Step 4 DIODE TEST

What was the resistance you measured? 8 Ω

What happened when you reversed the leads? high res in one direc

Why did it happen? Because diodes holds current flow to one direction

Instructor ______________

WORKSHEET 38

IAR ALTERNATOR STATOR & ROTOR BENCH TESTS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Find the bench test for an IAR alternator in the shop manual and perform the following tests:

Step 2 STATOR COIL GROUNDED TEST

What was the resistance you measured? +1 Ω

Step 3 STATOR COIL OPEN TEST

What was the resistance you measured? 1 Ω

Step 4 ROTOR OPEN OR SHORT TEST

What was the resistance you measured? 2,8 Ω

Instructor ____________________

ALTERNATOR ON VEHICLE TESTS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Find the charging system tests in the shop manual and perform the following tests:

Step 2 What type of alternator system is on the vehicle? ________ EVR ________ IAR

Step 3 BASE VOLTAGE

What was the voltage you measured? ________________V

Step 4 NO LOAD

What was the voltage you measured? ________________V

Step 5 LOAD

What was the voltage you measured? ________________V

Based upon the results of these tests, is the charging operating properly? _____ Yes _____ No

Based upon your earlier results, is OVER VOLTAGE test required? _____ Yes _____ No

Based upon your earlier results, is UNDER VOLTAGE test required? _____ Yes _____ No

Step 6 OVER VOLTAGE

What value did you measure, ohms, volts or amps?____________

What meter reading did you get? ________________________

What does the meter reading tell you? ______________________________

____

____

Step 7 UNDER VOLTAGE

What value did you measure, ohms, volts or amps?____________

What meter reading did you get? ________________________

What does the meter reading tell you? ______________________________

____

____

Step 8 REGULATOR S and I CIRCUIT (For EVR alternator systems only)

What was I terminal voltage? ________________V

What was S terminal voltage?________________V

Step 9 FUSE LINK CONTINUITY

Does the fuse link have continuity? _____ Yes _____ No

How did you determine your answer? ________________________

____

____

Step 10 FIELD CURRENT DRAIN

What voltage did you measure? ________________V

Is there a problem with the field circuit? _____ Yes _____ No

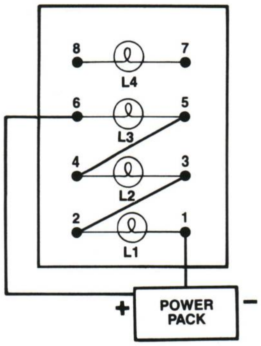
Instructor ____________________

WORKSHEET 46

OPENS IN SERIES CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS:



Step 1 — Using the wiring diagram above, complete the wiring on the light board.

Step 2 — Apply power to the circuit and make measurements.

Step 3 — Record results:

Meter Lead to Pin			DVOM	VOM	12 VOLT TEST LIGHT	
Black		Red			ON	OFF
1	—	2	______ V	______ V	______	______
1	—	4	______ V	______ V	______	______
1	—	6	______ V	______ V	______	______

OBSERVATIONS:

Step 4 — Disconnect jumper wire from pin 3 on light board.

Step 5 — Make measurements:

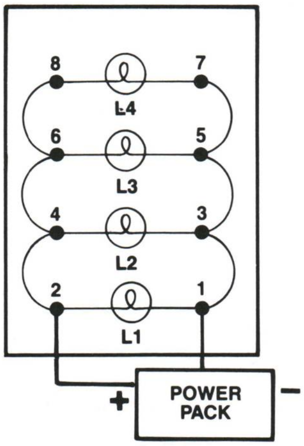
Meter Lead to Pin			DVOM	VOM	12 VOLT TEST LIGHT	
Black		Red			ON	OFF
1	—	2	______ V	______ V	______	______
1	—	4	______ V	______ V	______	______
1	—	6	______ V	______ V	______	______

OBSERVATIONS:

OPENS IN PARALLEL CIRCUITS

TECHNICIAN NAME: ________________________________

INSTRUCTIONS:



Step 1 — Using the wiring diagram above complete the wiring on the light board

Step 2 — Apply power to the circuit and make measurements

Step 3 — Record measurements:

Meter Lead to Pin			DVOM	VOM	12 VOLT TEST LIGHT	
Black		Red			ON	OFF
1	—	2	________ V	________ V	________	________
1	—	4	________ V	________ V	________	________
1	—	6	________ V	________ V	________	________

OBSERVATIONS:

Step 4 — Remove jumper between pins 4 and 6, to cause an open circuit on light board.

Step 5 — Make measurements.

Meter Lead to Pin			DVOM	VOM	12 VOLT TEST LIGHT	
Black		Red				
1	—	2	________ V	________ V	________	________
1	—	4	________ V	________ V	________	________
1	—	6	________ V	________ V	________	________
6	—	2	________ V	________ V	________	________

OBSERVATIONS:

OPENS IN PARALLEL CIRCUITS (Cont'd.)

Step 6 — Reconnect jumper between pins 4 and 6.

Step 7 — Cause open to light L_2 by disconnecting both alligator clips at pin 4 and connect the clips together.

Step 8 — Make measurements.

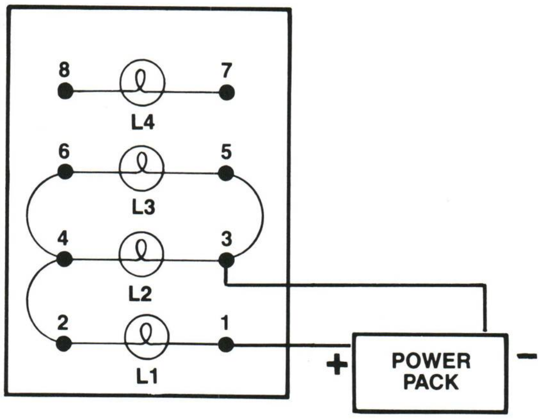
Meter Lead to Pin			DVOM	VOM	12 VOLT TEST LIGHT	
Black		Red			ON	OFF
1	—	2	________ V	________ V	________	________
1	—	4	________ V	________ V	________	________
1	—	6	________ V	________ V	________	________
3	—	2	________ V	________ V	________	________
4	—	2	________ V	________ V	________	________

OBSERVATIONS:

OPENS IN SERIES PARALLEL CIRCUITS

TECHNICIAN NAME: ____

INSTRUCTIONS:



Step 1 — Using the wiring diagram above complete the wiring on the light board. Set power pack at 12 volts and set amps fully clockwise.

Step 2 — Apply power to the circuit and make measurements using a DVOM, VOM and a 12 volt test light.

Step 3 — Record measurements:

Meter Lead to Pin			DVOM	VOM	12 Volt Test Light	
Black		Red			On	Off
3	—	1	________ V	________ V	_____	_____
3	—	2	________ V	________ V	_____	_____
3	—	4	________ V	________ V	_____	_____

Step 4 — Remove jumper between pins 4 and 2, to cause an open circuit on light board.

Step 5 — Make measurements:

Meter Lead to Pin			DVOM	VOM	12 Volt Test Light	
Black		Red			On	Off
3	—	1	________ V	________ V	_____	_____
3	—	2	________ V	________ V	_____	_____
3	—	4	________ V	________ V	_____	_____
4	—	1	________ V	________ V	_____	_____
5	—	1	________ V	________ V	_____	_____

OPENS IN SERIES PARALLEL CIRCUITS (Cont'd.)

OBSERVATIONS:

Step 6 — Connect jumper between pins 4 and 2.

Step 7 — Remove jumper between pins 4 and 6, to cause an open circuit on light board.

Step 8 — Make measurements:

Meter Lead to Pin			DVOM	VOM	12 VOLT TEST LIGHT	
Black		Red			ON	OFF
3	—	2	______ V	______ V	________	________
3	—	4	______ V	______ V	________	________
3	—	6	______ V	______ V	________	________
6	—	1	______ V	______ V	________	________
6	—	2	______ V	______ V	________	________

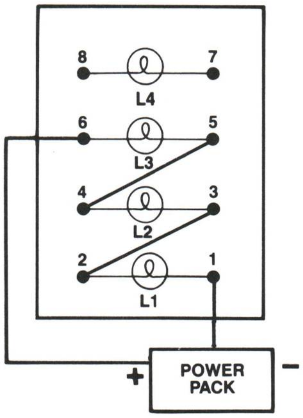
OBSERVATIONS:

WORKSHEET 49

WIRE TO WIRE AND WIRE TO GROUND SHORTS SERIES CIRCUITS

TECHNICIAN NAME: ____

INSTRUCTIONS:



Step 1 — Build series circuit hooking pin 1 to negative, pin 2 to 3, pin 4 to 5, pin 6 to positive.

Step 2 — Measure voltages and fill in column A in chart below.

Step 3 — Hook another jumper in series with the jumper between pins 4 and 5 and another jumper in series with the jumper from pin 6 to power. (Note: Where the jumper clips join together represents a worn spot on a wire.)

Step 4 — Touch the clips between pins 4 and 5 and pin 6 and power together. Observe the bulbs and record bright or dim.

Bulb L1 ______

Bulb L2 ______

Bulb L3 ______

Step 5 — Measure voltages and fill in column B in chart below.

Step 6 — Briefly describe what happened in step 4:

____

____

____

____

Step 7 — Touch the clips between pins 6 and power to pin 1 and describe what happened.

____

____

____

____

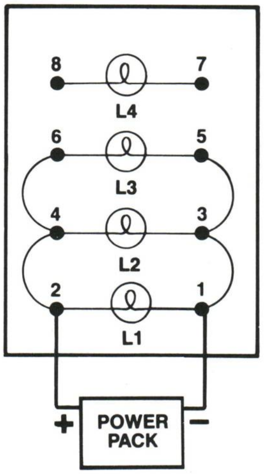
Meter Lead to Pin		Voltage Measurement	
Black	Red	A	B
1	2	______	______
1	4	______	______
1	6	______	______

INSTRUCTOR ____________________

WIRE TO WIRE AND WIRE TO GROUND SHORTS PARALLEL CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS:



Step 1 — Build parallel circuit hooking pin 1 to negative, pin 1 to 3, pin 3 to 5, pin 2 to positive, pin 2 to 4, pin 4, 6.

Step 2 — Measure voltages and fill in column A in chart below.

Step 3 — Hook another jumper in series with the jumper between pins 2 and 4 and another jumper in series with the jumper between pins 4 and 6. (Note: where the jumper clips join together represents a worn spot on the wire)

Step 4 — Touch the clips between pins 2 and 4 and pins 4 and 6 together.

Step 5 — Measure voltages and fill in column B in chart below.

Step 6 — Briefly describe what happened in step 4:

____

____

____

____

Step 7 — Touch the clips between pins 2 and 4 to pin 3. Now touch the clips to pin 5. Describe what happened.

____

____

____

____

Meter Lead to Pin		Voltage Measurement	
Black	Red	A	B
1	2	______	______
1	4	______	______
1	6	______	______

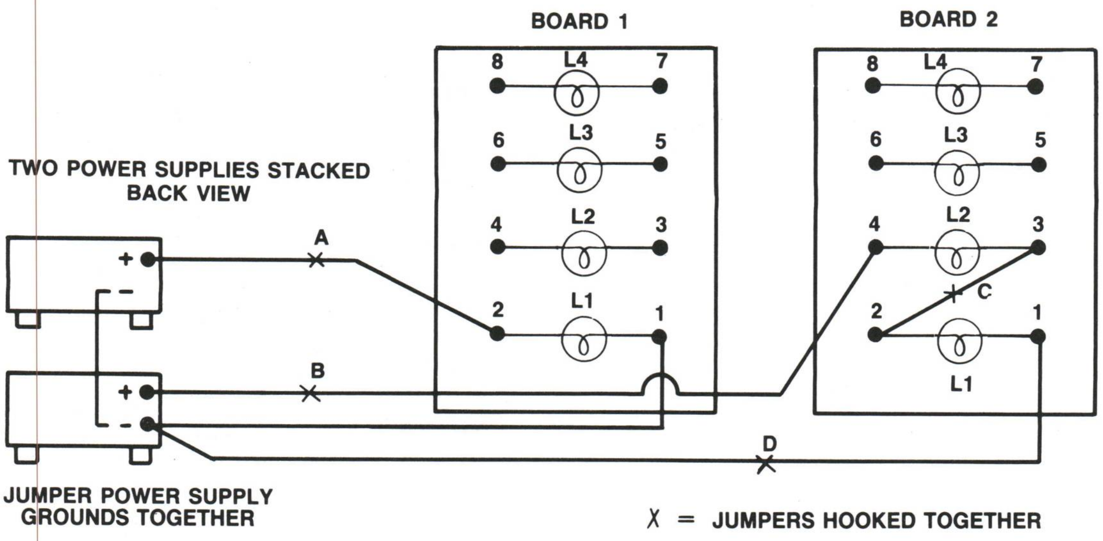
INSTRUCTOR ______________________________

WIRE TO WIRE AND WIRE TO GROUND SHORTS BETWEEN TWO SERIES CIRCUITS

TECHNICIAN NAME: ______________________________

INSTRUCTIONS:

Step 1 — Build circuits carefully following diagram. Work two groups together.



Note: Think of the power supplies as two separate fuses in the fuse block.

Step 2 — Measure voltages and fill in column A in chart below.

Step 3 — Short the clips Ⓐ and Ⓑ together. Make and record voltage measurements in column B.

Step 4 — Briefly describe what happened in step 3 and why.

Step 5 — Short the clips Ⓐ to Ⓒ together. Note anything unusual then make and record voltage measurements in column C.

Step 6 — Briefly describe what happened in step 5 and why.

Step 7 — Short the clips Ⓐ to Ⓓ together. Note anything unusual and make and record voltage measurements in column D.

WIRE TO WIRE AND WIRE TO GROUND SHORTS BETWEEN TWO SERIES CIRCUITS (Cont'd.)

Step 8 — Briefly describe what happened in step 7 and why.

____

____

____

____

Meter Lead to Pin		Voltage Measurement			
Black	Red	A	B	C	D
GRD	Board 1, Pin 2				
GRD	Board 2, Pin 2				
GRD	Board 2, Pin 3				
GRD	Board 2, Pin 4				

INSTRUCTOR ____________________

VEHICLE PROBLEM

TECHNICIAN NAME: ______________________________

INSTRUCTIONS: Determine the solution for the customer's problem.

Problem: Customer states the vehicle will not run.

Solution: ______________________________

____

____

____

____

Instructor ______________

VEHICLE PROBLEM

TECHNICIAN NAME: ______________________________

INSTRUCTIONS: Determine the solution for the customer's problem.

Problem: Customer states there is problem with headlights.

Solution: ______________________________

____

____

____

____

Instructor ______________

SOLDERING EXERCISE

TECHNICIAN NAME: ____________________

INSTRUCTIONS

Step 1 Place two pieces of heat shrink tubing on the wire.

Step 2 Solder two (2) wires together. When completed have instructor inspect your work and initial this worksheet.

Instructor ____________

Step 3 Solder a ring terminal onto the end of the wire. When complete have instructor inspect your work and initial this sheet.

Instructor ____________

Step 4 Place heat shrink tubing over the terminal/solder joint and heat it with a solder gun.

CRIMPING EXERCISE

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Crimp the following connectors to wires and have the instructor inspect each crimp.

A. Ring terminal to wire

Instructor ____________________

B. Butt connector to attach two (2) wires together.

Instructor ____________________

C. Bullet connector to wires and then connect male and female portions of connector together.

Instructor ____________________

HARDSHELL CONNECTOR REPAIR EXERCISE

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 Remove and replace a pin in each of the following hardshell connectors. Have the instructor inspect your repair.

A. Locking wedge connector

Instructor ______________

B. Tang type connector

Instructor ______________

C. Blade type connector

Instructor ______________

D. Internal locking finger

Instructor ______________

E. Printed circuit connector

Instructor ______________

TRIPMINDER TEST

TECHNICIAN NAME: ____________________

INSTRUCTIONS

Step 1 If vehicle available is a **FORD CROWN VICTORIA** or **MERCURY GRAND MARQUIS** with Tripminder, the technician will perform the following tests.

Check the operation of the tripminder using the **TIME, TRIP, ECON,** and **FUEL** buttons. Note any operational problems.

Time ____________________

Trip ____________________

Econ ____________________

Fuel ____________________

Step 2 Perform the Self Test. Note any problems during the self test.

Time ____________________

Trip ____________________

Econ ____________________

Fuel ____________________

S ____________________

EM ____________________

EM ____________________

EM ____________________

R ____________________

Step 3 Perform pinpoint tests A, B, and C. Note any problems.

Pinpoint Test A ____________________

____

Pinpoint Test B ____________________

____

Pinpoint Test C ____________________

____

Instructor ____________________

WHEEL ANTI-LOCK SYSTEM TEST

TECHNICIAN NAME: ____________________

INSTRUCTIONS

If vehicle available is a **MARK VII** or **THUNDERBIRD TURBO COUPE** with a Wheel Anti-Lock system, the technician will perform the following tests.

Step 1 Perform the On-board Self-test on the Anti-lock system. Note all codes and identify which pinpoint test the code indicates you should perform.

Code ____________ Pinpoint Test ____________

Code ____________ Pinpoint Test ____________

Code ____________ Pinpoint Test ____________

Code ____________ Pinpoint Test ____________

Code ____________ Pinpoint Test ____________

Code ____________ Pinpoint Test ____________

Code ____________ Pinpoint Test ____________

Step 2 Perform the Quick Test Checks. Note your results below.

Battery Check ____________

Main Power Relay ____________

Power From Main Power Relay ____________

Main Power Relay Circuit ____________

Sensor Resistance (RR) ____________

Sensor Resistance (LF) ____________

Sensor Resistance (LR) ____________

Sensor Resistance (RF) ____________

Main Valve Resistance ____________

Inlet and Outlet Valves ____________

Reservoir Warning ____________

Lift Fluid Level Indicator from Reservoir ____________

Sensor Cable Continuity to Ground (RR) ____________

Sensor Cable Continuity to Ground (LF) ____________

Sensor Cable Continuity to Ground (LR) ____________

Sensor Cable Continuity to Ground (RF) ____________

Sensor Voltage (RR) ____________

Sensor Voltage (LF) ____________

Sensor Voltage (LR) ____________

Sensor Voltage (RF) ____________

Instructor ____________

ELECTRONIC MESSAGE CENTER TEST

TECHNICIAN NAME: ____________________

INSTRUCTIONS

Step 1 If vehicle available is a **LINCOLN TOWN CAR** with electronic message center, the technician will perform the following tests.

Perform the Quick Functional Test. Note any problems found and the pin point test indicated.

QFT-1 ____________________
QFT-2 ____________________
QFT-3A ____________________
QFT-3B ____________________
QFT-4 ____________________
QFT-5 ____________________
QFT-6 ____________________
QFT-7 ____________________
QFT-8 ____________________
QFT-9 ____________________
QFT-10 ____________________
QFT-11 ____________________
QFT-12 ____________________
QFT-13 ____________________
QFT-14 ____________________
QFT-15 ____________________
QFT-16 ____________________
QFT-17 ____________________
QFT-18 ____________________
QFT-19 ____________________
QFT-20A ____________________
QFT-21 ____________________
QFT-22 ____________________
QFT-23 ____________________
QFT-24 ____________________
QFT-25 ____________________
QFT-26 ____________________
QFT-27 ____________________
QFT-28 ____________________
QFT-29 ____________________

Instructor ____________________

ELECTRONIC INSTRUMENT PANEL TEST

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 If vehicle available is a THUNDERBIRD or COUGAR with an Electronic Instrument Panel, the technician will perform the following tests.

Perform the Tachometer/Multigauge Self Test. Note any tests that fail and the pinpoint test indicated.

Test 1 ______________________________
Test 2 ______________________________
Test 3 ______________________________
Test 4 ______________________________
Test 5 ______________________________
Test 6 ______________________________
Test 7 ______________________________

Step 2 Perform the Speedometer/Odometer Self Test. Note any tests that fail and the pinpoint test indicated.

Test 1 ______________________________
Test 2 ______________________________
Test 3 ______________________________
Test 4 ______________________________
Test 5 ______________________________
Test 6 ______________________________
Test 7 ______________________________
Test 8 ______________________________
Test 9 ______________________________
Test 10 ______________________________

Step 3 Perform the Fuel Computer Self Test. Note any tests that fail and the pinpoint test indicated.

Inst Econ ______________________________
Ave Econ ______________________________
DTE ______________________________
Distance ______________________________
Ave Speed ______________________________

Instructor ____________________

DIGITAL SPEEDOMETER TEST

TECHNICIAN NAME: ______________________________

INSTRUCTIONS

Step 1 If vehicle available is a THUNDERBIRD or COUGAR with a Digital Speedometer, the technician will perform the following tests.

Perform the Speedometer/Odometer Self Test. Note any tests that fail.

Test 1 ______________________________

Test 2 ______________________________

Test 3 ______________________________

Test 4 ______________________________

Test 5 ______________________________

Test 6 ______________________________

Test 7 ______________________________

Test 8 ______________________________

Test 9 ______________________________

Test 10 ______________________________

Instructor ______________

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